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ADDITIONS TO OUR KNOWLEDGE OF THE RUSTS OF HYDERABAD—I

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Introduction

It is proposed to describe in a series of papers the occurrence of Uredinales in the Hyderabad State. In an earlier communication six species of rusts have been reported by Ramachar and Salam (1954). The present paper records twelve more species of rusts collected in and around the vicinity of Hyderabad and which do not seem to have been reported before. Species recorded for the first time from India are indicated by an asterisk.

1. *Cerotelium fici* (Cast.) Arth., in *Bull. Torrey. bot. Cl.*, **33**: 30, 1906; Butler, E. J. and Bisby, G. R. in Sci. Monogr. No. 1, Coun. Agr. Res. India, p. 56, 1930.

Hab.—On living leaves of *Ficus hispida* L., Government Fisheries Farm, Hyderabad. Leg. P.R. and M.A.S. (11 Dec. 1954). O.U.B. Herb. 'Hy.' No. 7. The rust occurring on cultivated figs has been reported from Hyderabad (Vaheeduddin, Salam and Ramachar, 1954). The host is an additional record.

2. *Puccinia chrysopogi* Barcl., in *Descript. List Ured. Simla*, **2**: 247; Butler, E. J. and Bisby, G. R. in Sci. Monogr. No. 1, Coun. Agr. Res. India, p. 65, 1930.

Hab.—On the leaves of *Chrysopogon montanus* Trin., Aurangabad. Leg. M.A.S. (19 Sept. 1953). O.U.B. Herb. 'Hy.' No. 8. The host seems to be a new record for India.

3. *Puccinia heterospora* Berk. and Curt., in *J. Linn. Soc.*, **10**: 356; Butler, E. J. and Bisby, G. R. in Sci. Monogr. No. 1, Coun. Agr. Res. India, p. 68, 1930.

Hab.—On the living leaves and petioles of *Sida veronicæfolia* Lamk., Narasapur forest. Leg. P.R. (22 Sept. 1954). O.U.B. Herb. 'Hy.' No. 9.

Only telia were present. The rust has been reported on *Sida cordifolia* L., *Sida humilis* Willd., *Sida spinosa* L., and *Sida mysorensis* W. & A. by Butler from other parts of India. Yadav (1953) recorded the rust on the present host for the first time from Bihar. Ramachar and Salam (1954) reported it earlier on *Sida spinosa* L.

4. *Puccinia abutili* Berkeley and Broome, in *J. Linn. Soc. Bot.*, **14**: 91, 1875; Ramakrishnan, K. and Subramanian, C. V. in Fungi of India, Suppl. 2, *J. Madras Univ.*, B, **22**: 37, 1952.

Both uredia and telia were present.

Hab.—On the living leaves of *Abutilon crispum* G. Don., Osmania University campus. Coll. Miss Susheela and Miss Padmadevi (16 Nov. 1954). O.U.B. Herb. 'Hy.' No. 10. The host seems to be an additional record for India.

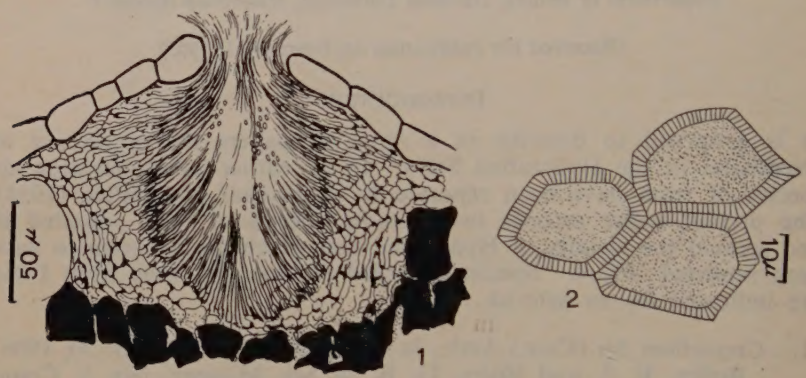

FIG. 1. Pycnium of *Aecidium leeæ* showing the ostiolar paraphyses and the pycniospores. FIG. 2. Aeciospores of *Aecidium leeæ*.

5. *Puccinia leiocarpum* (Syd.) Thirumalachar, in *Proc. Indian Acad. Sci.*, B, **14**: 446, 1941; Ramakrishnan, K. and Subramanian, C. V. in Fungi of India, Suppl. 2, *J. Madras Univ.*, B, **22**: 38, 1952.

Both æcia and telia were present.

Hab.—On the living leaves of *Ocimum adscendens* Willd., Narasapur forest and Osmania University campus. Leg. P.R. (September and October 1954). O.U.B. Herb. 'Hy.' No. 11.

6. *Puccinia leonotidicola* P. Henn., in *Bot. Ergebn. der Kunene Sambes. Exped.*, p. 3, 1902; Butler, E. J. and Bisby, G. R. in Sci. Monogr. No. 1, Coun. Agr. Res. India, p. 69, 1930.

Both uredia and telia were present.

Hab.—On the stem, petiole and leaves of *Leonotis napetæfolia* R. Br., Vikarabad, Mannanoor forests and Osmania University campus. Leg. P.R. and M.A.S. (Nov. 1954). O.U.B. Herb. 'Hy.' No. 12.

7. *Puccinia lateripes* Berk. and Rav., in *Grevillea* **3**: 52; Butler, E. J. and Bisby, G. R. in Sci. Monogr. No. 1, Coun. Agr. Res. India, p. 69, 1930.

Both uredia and telia were present.

Hab.—On the living leaves of *Ruellia* sp., Narasapur forest. Leg. P.R. (6 Dec. 1954). O.U.B. Herb. 'Hy.' No. 13.

8. *Uromyces commelinæ* Cooke, in *Trans, Roy. Soc. Edin.*, p. 342, 1887; Butler, E. J. and Bisby, G. R. in Sci. Monogr. No. 1, Coun. Agr. Res. India, p. 81, 1930.

Only telia were present.

Hab.—On the stems and leaves of *Commelina bengalensis* L., Osmania University campus. Leg. M.A.S. (24 Nov. 1954). O.U.B. Herb. 'Hy.' No. 14.

9. *Uromyces leptodermus* Syd., in *Ann. mycol.*, **4**: 430, 1906; Butler, E. J. and Bisby, G. R. in Sci. Monogr. No. 1, Coun. Agr. Res. India, p. 82, 1930.

Both uredia and telia were present.

Hab.—On the foliage of *Brachiaria distachya* Stapf., Agricultural College Farm, Osmania University. Leg. P.R. (10 Nov. 1954). O.U.B. Herb. 'Hy.' No. 15.

10. *Uromyces decoratus* Syd., in *Ann. mycol.*, **5**: 491, 1907; Butler, E. J. and Bisby, G. R. in Sci. Monogr. No. 1, Coun. Agr. Res. India, p. 81, 1930.

Both uredia and telia were present.

Hab.—On the living leaves of *Crotalaria juncea* L., Osmania University campus. Leg. M.A.S. (24 Nov. 1954). O.U.B. Herb. 'Hy.' No. 16.

11. *Uromyces orientalis* Syd., in *Ann. mycol.*, **5**: 490, 1907; Butler, E. J. and Bisby, G. R. in Sci. Monogr. No. 1, Coun. Agr. Res. India, p. 83, 1930.

Both uredia and telia were present.

Hab.—On the living leaves of *Indigofera cordifolia* Heyne, Osmania University campus. Leg. P.R. and M.A.S. (24 Nov. 1954). O.U.B. Herb. 'Hy.' No. 17.

12. ***Aecidium leeæ** Salam and Ramachar sp. nov.

Pycnia subepidermal, at first immersed, closed, flask-shaped, with ostiolar paraphyses, pycniospore measuring 1·6 μ in diameter. Pycnia measuring 117–42 μ. Aecia hypophyllous, arranged in irregular concentric circles. Each æcium light yellow in colour, columnar, and projecting beyond the surface, cylindrical, dehiscing at the apex. Peridum well developed, one-cell thick, margin lacerate. Aeciospores

arising from the hymenium at the base of the æcial cup, angular with striated wall, measuring $23 \cdot 35 \times 19 \cdot 32 \mu$.

Hab.—On the living leaves of *Leea macrophylla* Roxb., Osmania University campus. Leg. P.R. and M.A.S. (October 1954). Specimen deposited in the Herb. 'Hy.' Botany Department, Osmania University.

No rust occurring on this host has been reported so far from India. Pycnia appeared on 17th October 1954 and a week later were followed by æcia. Further studies are in progress.

Aecidium leeæ Salam et Ramachar sp. nov.

Pycnia subepidermalia, primo immersa, clausa, urceoliformia, ornata paraphysibus ostiolaribus; pycnosporæ $1 \cdot 6 \mu$ diam., pycnia $117–42 \mu$. Aecia hypophylla, disposita in circulos irregulares concentricos, pallide lutea, columnaria, eminentia super superficiem, cylindrica, dehiscentia in apice. Peridium bene evolutum, una cellula crassum, marginibus laceratis. Aeciosporæ surgentes ex hymenio ad basim æcii, angulares, parietibus striatis, magnitudinis $23 \cdot 35 \times 19 \cdot 32 \mu$.

Typus lectus in foliis viventibus *Leeæ macrophyllæ* Roxb. in campo universitatis Osmania a P.R. et M.A.S. mense octobri 1954 (pycniis atque æciis tantum præsentibus), et positus in Herb. 'Hy.' Botany Department, in universitate Osmania.

Summary

In this paper twelve species of rusts, *viz.*, *Cerotelium fici* (Cast.) Arthur, *Puccinia chrysopogi* Barcl., *Puccinia heterospora* Berk. and Curt., *Puccinia abutili* Berk. and Br., *Puccinia leiocarpum* (Syd.) Thirumalachar, *Puccinia leonotidicola* P. Henn., *Puccinia lateripes* Berk. and Rav., *Uromyces commelinæ* Cooke, *Uromyces leptodermus* Syd., *Uromyces decoratus* Syd., *Uromyces orientalis* Syd. and *Aecidium leeæ* sp. nov. have been reported for the first time from Hyderabad. Additional hosts have been recorded for three species and the rust reported on *Leea* seems to be a new species.

Acknowledgments

The authors are indebted to Prof. M. Sayeedud-Din for his kind help, suggestions and encouragement, and also to Prof. T. S. Sadasivan, Dr. M. J. Thirumalachar and Dr. C. V. Subramanian for their valuable suggestions. Our thanks are also due to Rev. Dr. H. Santapau for the Latin diagnosis and to Dr. M. R. Suxena for identification of grasses. We are also thankful to Messrs. Sri Ramloo and P. K. Swami for the photographs.

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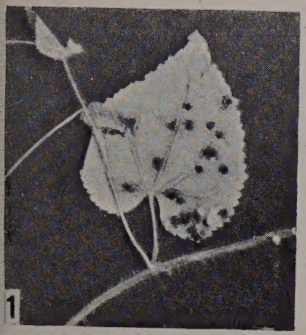
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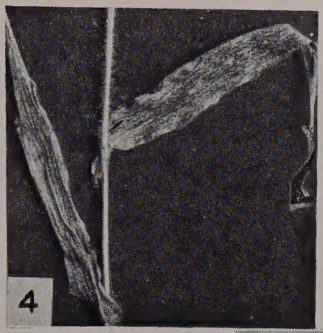
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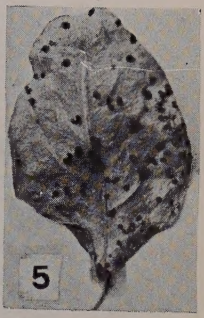
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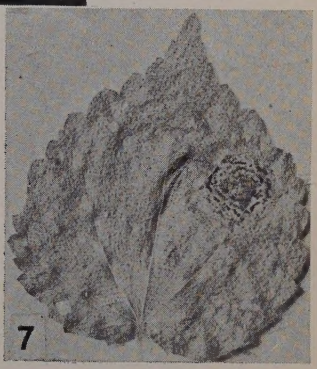
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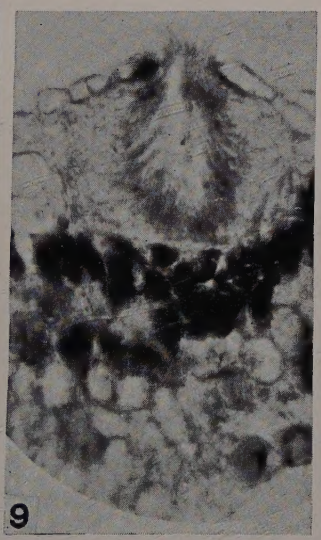
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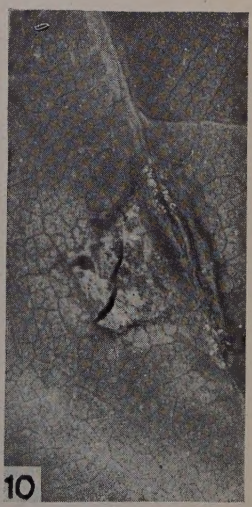
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. A. Salam and P. Ramachar

Explanation of the Plate

Fig. 1. *Abutilon crispum* showing the presence of telia of *Puccinia abutili.*

Fig. 2. *Crotalaria juncea* showing the presence of telia of *Uromyces decoratus.*

Fig. 3. *Indigofera cordifolia* showing the presence of telia of *Uromyces orientalis.*

Fig. 4. *Brachiaria distachya* showing the presence of telia of *Uromyces leptodermus.*

Fig. 5. *Ruellia* sp. showing the presence of telia of *Puccinia lateripes.*

Fig. 6. *Ocimum adsendense* showing the presence of telia of *Puccinia leiocarpum.*

Fig. 7. *Sida veronicæfolia* showing the presence of telia of *Puccinia heterospora.*

Fig. 8. *Commelina bengalensis* showing the presence of telia of *Uromyces commelinæ.*

Fig. 9. Photomicrograph of the transverse section of the leaf of *Leea macrophylla* showing the pycnium of *Aecidium leeæ.*

Fig. 10. A portion of the leaf of *Leea macrophylla* showing the æcia of *Aecidium leeæ.*

A BOTANICAL TOUR TO PARASNATH HILL, BIHAR

By J. G. Srivastava

Science College, Patna ; now at the National Botanic Gardens, Lucknow

(With one map)

(Received for publication on February 23, 1955)

General

Parasnath Hill (23·9′ N. lat. and 86·3′ E. long.) is the highest in the Province (Bihar). About 25 Jain shrines are located on the top, one on each of the rocky peaks; the biggest, the one devoted to Saint Parasnath, being built on the highest peak, 4,480 feet above sea-level.

The hill is approached from Parasnath railway station by two routes, one *via* Madhuban on the northern side of the hill and the other *via* Nimiaghat on the eastern side of the hill. The first route is frequented by a large number of pilgrims who come during the winter from all over India, halt in the dharamshalas at Madhuban, and from there climb up the hill. The other route is used by the government officers, tourists, etc., who want to stay in the dak-bungalows at Nimiaghat and at the top (please see the attached map). The climb up the hill is about 6 miles from either side, the path being fairly steep by the Madhuban route. After a climb of about 4 miles by this route, the path bifurcates, one goes due south to Jal-Mandir where the devotees bathe before visiting the shrines, the second one goes south-west to the dak-bungalow. The Nimiaghat route goes direct to the dak-bungalow. From both Jal-Mandir and the dak-bungalow, one has to climb about 300 feet to reach the highest peak.

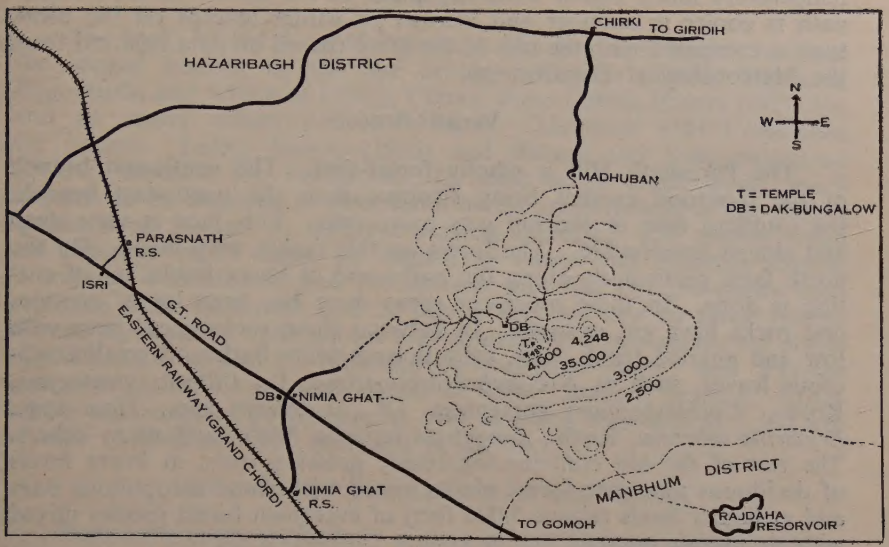
Physical Features

The Tundi range, one of the outlying spurs of the Hazaribagh-Ranchi plateau, itself the eastward termination of the huge Satpura-Vindhyan massif, extends across the boundary of Manbhum and Hazaribagh districts and to the east of Hazaribagh District. It forms the water-parting between the Damodar river on the south and the Barakar river on the north, and contains the highest hill in the province, Parasnath.

Parasnath Hill has a central narrow ridge, about 4 miles long and 2 miles wide, irregular in shape but taking the general configuration of a crescent, its ends pointing to the north-east and north-north-west. In these directions, the principal spurs of the hill extend. On the south-west there are no spurs, and the greatest continuous rise occurs.

Geology

The highest part of Parasnath Hill and most of the cliffs are made up of pyroxene-quartzite, a hard rock which resists denudation and is



Map showing Parasnath Hill and Its Neighbourhood

responsible for the precipitous nature of the slopes. The lower portion of the hill is composed of quartzo-felspathic pink gneiss which weathers easily and gives rise to gentler slopes. The lower soils are more clayey, whereas the upper ones are more sandy (Chatterji, 1934).

Climate

The climate is of the monsoon type, the hot wet months being April-October. The rainfall of about 60 inches per annum is derived from the Bay of Bengal current of the monsoon, from the branch which runs north, and becoming deflected by the Himalayas, sweeps up the Gangetic plains and areas further south, as also from the branch, which comes from the south-east and strikes the hills of South Bihar directly. There is some little rain in winter from the Arabian Sea current of the monsoon.

Strong winds blow all the year round, the velocity is 10–15 miles per hour up to 3,500 feet and about 25 miles per hour at the top. They blow at 1,600 feet from south and south-west in April-September, from north-east in October and from north-west and west in November-March. At 3,300 feet the wind blows from north-west in October-April, from south-west and west in May-June and from south-east in July. At the top the direction is from north-east and north-east-east in July-August, and from north and north-west during the rest of the year (based on the Climatological Atlas for the Airmen).

The relative humidity on Parasnath upto about 4,000 feet altitude is about 80 on the average, and much higher during the rainy season. The mean maximum temperature is much lower and the mean minimum

temperature much higher than any place in the State. In fact, Parasnath is cooler in summer and warmer in winter (except on the bleak top) as compared with the rest of the State (based on data received from the Meteorological Department).

Vegetation

The Parasnath Hill is wholly forest-clad. The south-east branch of the monsoon current being stronger than the north-east branch, the southern face of the hill gets more rain. This face is very steep and almost inaccessible. The forest on this face is very thick. On the north face, particularly along the paths and at lower levels, lot of cutting is done. In these much-cut areas there has been lot of erosion, and rocks have got exposed. In between these rocks grow trees with low and gnarled trunk, thin, smooth and white bark and small coriaceous leaves, such as *Nyctanthes arbor-tristis*, L., *Dillenia pentagyna*, Roxb., *Cochlospermum gossypium*, DC., *Gardenia* spp., *Ficus* spp., *Erythrina suberosa*, Roxb., *Anogeissus latifolia*, Wall., and many others. The rest of the hill contains vigorously growing trees, at lower levels of deciduous monsoon forest plants mixed with some xerophilous ones and at higher levels (above 3,000 feet) of evergreen forest species mixed with deciduous ones.

In the deciduous forest region, the trees are tall, straight and close together, and the under-growth is thick. There are huge lianas growing from tree to tree. Lots of mistletoes and epiphytic orchids grow on the trunks of trees. Bamboos are frequent. During the monsoons, many rhizomatous and bulbous plants are seen.

In the evergreen forests that occur between 3,000–4,000 feet, the condition is similar to the above, except that the species are different. There are few mistletoes, and the epiphytes are a different set of orchids, *Peperomia reflexa*, A. Dietr., *Tripogon capillatus*, Jaub and Spach., various mosses and lichens.

The very top, beyond 4,000 feet, contains evergreen trees with stunted growth, as also some alpine plants, in addition to the many low grasses and annuals that grow up during the rains. It, therefore, appears bare as compared to the rest of the hill.

The typical scrub jungle is found nowhere on the hill, the few xerophilous species that are seen on the exposed faces of the hill and in the much-cut areas, once occupied a large part of the hill when unrestricted cutting and grazing was allowed. With strict conservancy for the last 50 years or so, the vegetation has improved.

The hot weather firing in March with the object of improving the grass and the growth of sal, is inimical to the growth of the evergreen species. If left to itself, the evergreen forest should have encroached upon the deciduous. It is also because of firing that bulbous and rhizomatous herbs (especially grasses) and dwarf shrubs are seen, instead of the species usually found in the evergreen forests.

The general character of vegetation is tropophilous.

Floristics

The study of the flora of Parasnath Hill has been made ever since the second quarter of the last century. Hooker (1848), Thomson, Edgeworth, and Anderson (1863), Clarke, Prain (1903), Haines (1921–25), and so many others collected there. Thomson (1917) described the botany. Lately Biswas (1935) and Biswas and Sampatkumaran (1949 *a*) describe the vegetation. In spite of so much work, much remains to be explored at Parasnath, as the observations of the author spread over 5 years in different seasons indicate. The author noted the presence of 39 trees, 35 shrubs, 28 lianas and climbing shrubs, 3 orchids, 4 mistletoes, and 146 annuals that had not previously been recorded from Parasnath and 26 others that are new to Bihar (please see the Appendix). The author also found that some interesting plants like *Santalum album*, L., *Kalanchœ heterophylla*, Prain., and *Pygeum andersoni* Hook. f., are now not to be seen. *Berberis asiatica*, Roxb. which was reported by Hooker in 1848 as being abundant at 3,500 feet is now located at 4,200 feet and is scarce.

Reasons for the Change in the Flora

Parasnath is geographically a part of the Deccan plateau. Vegetationally also it falls in the Deccan Province of Hooker (1904), which includes the whole of South Bihar, Madhya Pradesh, Orissa and North-East Madras and is characterized by sal-dominated deciduous monsoon forest. This type of forest is also found in the foot hills of the Himalayas. As the climate and soil are nearly similar, introduction of plants belonging to this zone is possible on Parasnath Hill both from the Himalaya side as also from Madhya Pradesh and Orissa side.

Parasnath Hill has a large number of evergreen and alpine plants similar to those on the Himalayas, particularly Eastern, and to the hills of the Deccan Peninsula as has been shown by [Burkill (1910, 1924), Smith and Cave (1911), Smith (1913), Fischer (1921, 1938), Gowan (1929), Fyson (1932), Kanjilal and Das (1934), Mukerji (1940), Biswas and Sampatkumaran (1949 *b*), and Mooney (1950)]. Their presence on Parasnath was explained by Haines (1921–25) as being relic from the time when the hills of Chota Nagpur and Orissa were much higher and were serving as stepping-stones for the passage of species from the highlands of the Deccan Peninsula to the newer Himalayas and in some cases in a reverse direction. Biswas and Sampatkumaran (1949 *b*) feel they are a relic from the time when there was land connection between the Deccan Peninsula and the Indo-Malayan region. From the new records of so many Himalayan plants on Parasnath, it appears to the author that the plants are not relic but that exchange of floras is taking place between Parasnath Hill and both the Himalayas and the hills of Deccan even now. They are not very far apart. Vogler (Wulff, 1950) showed that transport of seeds by wind to long distances even for hundreds of kilometres is possible. Mehta (1952) also showed that spores of *Puccinia* are blown down from the Himalayas for thousands of miles once they are lifted up by the up-valley currents to the upper air-currents. We have seen that strong upper-air currents blow over Parasnath

from one direction or the other all the year round. These can easily bring dust seed and plumed seeds and fruits from the South India hills, the Central India hills, Assam hills and the Himalayas. The migratory birds are also responsible for the introduction of many plants from the Himalayas as also from the Deccan Peninsula.

The pre-requisite for introduction is the presence of an open habitat. We have already seen that there is a lot of cutting and burning. These create clearings which can be peopled by plants constantly being brought in by winds, birds and human beings. The faces of the cliffs are precipitous. Rains fall in torrents and strong winds blow in full force, so that landslides occur. These may offer an opportunity for the new introductions to get a foothold.

The disappearance of certain species is due both to a change of climate, as is happenning on the top, near Jal-Mandir and elsewhere, and to too much exploitation by man, as in the case of *Berberis asiatica*, Roxb., *Rubia cordifolia*, L., *Seigesbeckia orientalis*, L. and other plants of medicinal and economic importance.

The author takes opportunity to thank Dr. K. Biswas, Superintendent, Indian Botanic Gardens, Calcutta, for identification of many specimens, Dr. D. Chatterji, Systematic Botanist, Indian Agricultural Research Institute, New Delhi, for suggesting many improvements in the manuscript, and Prof. K. N. Kaul, Director, National Botanic Gardens, Lucknow, for encouragement during the course of the work.

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APPENDIX

A complete list of plants collected by the author from Parasnath Hill. The arrangement of natural orders has been kept as in Haines' *Botany*. No attempt has been made to bring the nomenclature up-to-date so as to keep consistency with Haines. A single arrow mark after the name indicates that the plant occurs in the next altitudinal zone also, and two arrow marks mean that it occurs in the two next altitudinal zones. An asterisk before the name indicates that the plant is being recorded for the first time at Parasnath Hill, and a dagger means that it is a new record for Bihar.

Trees

Up to a height of 2,000 *feet*

**Dillenia pentagyna*, Roxb.
**Annona squamosa*, L.
**Homalium nepalense*, Benth.
**Flacourtia ramontchi*, L. Herit.
**Casearia graveolens*, Dalz.
**C. tomentosa*, Roxb.
Cochlospermum, gossypium DC.—
Shorea robusta, Gaertn.
**Kydia calycina*, Roxb.
Bombax malabaricum, DC.
**Croton oblongifolius*, Roxb.
**Mallotus philippinensis*, Muell.—
**Emblica officinalis*, Gaertn.
Aegle marmelos, Correa.
**Feronia elephantum*, Correa.
Azadirachta indica, A. Juss.
Cedrela toona, Roxb. —
Zizyphus jujuba, Lamk.
Schleichera trijuga, Willd.
**Buchanania latifolia*, Roxb.
**Semecarpus anacardium*, L.
Mangifera indica, L.
Butea frondosa, Roxb.
**Pterocarpus marsupium*, Roxb.
Sophora bakeri, Clarke.
Cassia fistula, L.
Bauhinia variegata, L.
B. malabarica, Roxb.
**Terminalia belerica*, Roxb.
T. chebula, Retz.
T. arjuna, W. & A. —
**Anogeissus latifolia*, Wall.
**Eugenia heyneana*, Wall.
**Psidium guayava*, L.
**Lagerstroemia indica*, L.
**L. parviflora*, Roxb.
**Hymenodictyon excelsum*, Wall.
**Wendlandia exserta*, DC.
**W. tinctoria*, DC.
**Gardenia turgida*, Roxb.
**G. latifolia*, Aiton.
**Ardisia depressa*, Clarke.
Diospyros embryopteris, Pers.
**D. cordifolia*, Roxb.
**D. melanoxylon*, Roxb.
**Bassia latifolia*, Roxb.
**Oroxylum indicum*, Vent.
**Premna latifolia*, Roxb. var. *mucronata*, Clarke.
**P. benghalensis*, Clarke. — —
Artocarpus lakoocha, Roxb.
**A. integrifolia*, L.f.
**Ficus infectoria*, Roxb.
**F. glabella*, Blume.
**F. tomentosa*, Roxb.

Between 2,000 *and* 4,000 *feet*

**Schrebera swietenoides*, Roxb.
Callicarpa arborea, Roxb.—
Litsaea polyantha, Juss.
**Ficus comosa*, Roxb.
**F. retusa*, L.
**F. cunia*, Ham.
**F. macrophylla*, Roxb.

Shrubs

Up to a height of 2,000 *feet*

**Thespesia lampas*, Dalz.
**Helicteres isora*, L.
**Grewia hirsuta*, Vanb.
**G. multiflora*, Juss.
**G. disperma*, Rottl.
G. sapida, Roxb.
G. rothi, DC.
Jatropha curcas, L.
Bridelia verrucosa, Haines.
**Bridelia montana*, Willd.
**Flueggia obovata*, Baill.
Gymnosporia montana, Benth.

Leea aspera, Edgew.
**L. crispa*, L.
Erythrina suberosa, Roxb.
Pueraria tuberosa, DC.
**Desmodium pulchellum*, Benth.
D. polycarpum, DC.
**D. laxiflorum*, DC.
**D. latifolium*, DC.—
**Flemingia chappar*, Ham.
F. paniculata, Wall.
**F. congesta*, Roxb.
†*F. lineata*, Roxb.
**Woodfordia fruticosa*, Kurz.
**Mitragyna parviflora*, Korth.
Ixora undulata, Roxb.
**Pavetta indica*, L.
Canthium didynum, Roxb.
**Hamiltonia suaveolens*, Roxb.
Nyctanthes arbor-tristis, L.
**Lantana camara*, L.
**Vitex peduncularis*, Wall. var. *roxburghiana*
**Clerodendron serratum*, Spreng.
**Hyptis suaveolens*, Poit.
Pogostemon plectranthoides, Desf.
Colebrookia oppositifolia, Sm.
**Anisomeles indica*, O. Kuntz.
**Trema orientalis*, Blume.
**Salix tetrasperma*, Roxb.
**Dendrocalamus strictus*, Nees.

Between 2,000 *and* 4,000 *feet*

**Indigofera pulchella*, Roxb.—
**Desmodium gyrans*, DC.—
**D. gyroides*, DC.
**Alangium lamarkii*, Thw.
**Symplocos racemosa*, Roxb.
**Linociera intermedia*, Wight.
†*Machilus sericea*, Blume.
**Bambusa arundinacea*, Willd.

Above 4,000 *feet*

Berberis asiatica, Roxb.
Pittosporum floribundum, W. & A.
Grewia spp.
†*Zizyphus funiculosa*, Lamk.
Acacia donaldi, Haines.
**Buddleia asiatica*, Lour.
**Boehmeria platyphylla*, Don.
Vangueria spinosa, Roxb.

Climbers and Stragglers

Up to 2,000 *feet*

**Stephania hernandifolia*, Walp.
Cissampelos pareira, L.
**Tragia involucrata*, L.
**Olax scandens*, Roxb.
Celastrus paniculata, Willd.
**Zizyphus oenoplia*, Mill.
**Z. rugosa*, Lamk.
**Gouania leptostachya*, DC.
**Helinus lanceolatus*, Brand.—
**Vitis tomentosa*, Heyne.
**V. bractoelata*, Wall.
**Milletia auriculata*, Baker.—
Dolichos biflorus, L.
**Rhynchosia rufescence*, DC.
**Atylosia crassa*, Prain.
Mucuna imbricata, DC.
**Vigna vexillata*, Benth.
Acacia concinna, DC.
**Combretum decandrum*, Roxb.
**Jasminum pubescence*, Willd.
**J. scandens*, Vahl.—
**J. arborescence*, Roxb. var *Roxburghianum*, Wall.
**Aganosma caryophyllata*, G. Don.
**Hemidesmus indicus*, Br.
**Porana paniculata*, Roxb.
**Asparagus racemosus*, Willd.
**Smilax macrophylla*, Roxb.
**S. prolifera*, Roxb.—
**S. roxburghiana*, Wall.

Between 2,000 *and* 4,000 *feet*

**Vitis lanceolaria*, Lawson.
**V. pedata*, Vahl.
**Bauhinia anguina*, Roxb.—
**B. vahlii*, W. & A.
**Mezoneuron cucullatum*, W. & A.
**Jasminum strictum*, Haines.
†*Ficus foveolata*, Wall.
F. scandens, Roxb.
†*F. thwaitsii*, Miq.

Above 4,000 *feet*

**Clematis nutans*, Royle.
†*C. buchanania* DC.
C. gouriana, Roxb.

Epiphytes

Up to 2,000 *feet*

Oberonia falconeri, Hk.
Vanda parviflora, Lindl.
V. tessellata, Hook.
Aerides multiflorum, Roxb.—
Heptapleurum venulosum, Seems.—

Above 2,000 *feet*

Peperomia reflexa, A. Dietr.
Remusatia vivipara, Schott.
Tripogon capillatus, Jaub. & Spach.
**Dendrobium bicameratum*, Lindl.
**Pholidota imbricata*, *Lindl.*
**Luisia trichorrhiza*, Blume.

Parasites

Up to 2,000 *feet*

Alectra indica, Benth.—
Aeginetia indica, Roxb.—
Cassytha filiformis, L.
Loranthus longiflorus, Desr.
**L. scurrula*, L.
**Viscum orientale*, Willd.—
Viscum articulatum, Burm.

Herbs, Annual Climbers and Grasses

Up to 2,000 *feet*

Ionidium suffruticosum, Ging.
**Polygala chinensis*, L.
Sida acuta, Burm.
**S. glutinosa*, Dav.
**S. spinosa*, L.
**Hibiscus tetraphyllus*, Roxb.
**H. panduræformis*, Burm.
Urena lobata, L.—
**U. sinuata* L.—
Triumfetta neglecta, W. & A.
T. rhomboidea, Jacq.
**Corchorus trilocularis*, L.
**C. acutangulus*, Lamk.
**Phyllanthus maderaspatensis*, L.
P. urinaria, L.
**P. debilis*, Ham.
**Biophytum sensitivum*, DC.
**Oxalis corniculata*, L.—
Cardiospermum halicacabum, L.
**Crotalaria albida*, Heyne.
**C. linifolia*, L.
Indigofera linifolia, Retz.
**I. hirsuta*, L.
**Zornia diphylla*, Pers.—
**Desmodium triflorum*, DC.
**D. gangeticum*, DC.
**Uraria alopecuroides*, Wight.
**U. pulchra*, Haines.
**Alysicarpus bupleurifolius*, DC.
**A. monilifer*, DC.
**Rhynchosia minima*, DC.
Atylosia scaraboides, Benth.
**Phaseolus calcaratus*, Roxb.
P. sublobatus, Roxb.
**P. mungo*, L. var. *roxburghii*, Prain.
**Cassia pumila*, Lamk.
**Oldenlandia dichotoma*, Kœn.
**O. paniculata*, L.
Spermacoce stricta, L.f.
**S. hispida*, L.
Knoxia corymbosa, Bl.
**Vernonia cinerea*, Less.
**V. teres*, Wall.—
**Elephantopus scaber*, L.
**Ageratum conyzoides*, L.—
**Cyathocline lyrata*, Cass.—
**Conyza ægyptica*, Ait.
C. viscidula Wall.
**Blumea atropurpurea*, Haines.
**Blumea laciniata*, DC.
Laggera alata, Schultz-Bip.
†*Vicoa cernua*, Dlaz.
**Eclipta alba*, Haask.
**Blainvillea latifolia*, DC.—
**Bidens pilosa*, L.
**Cotula anthemoides*, L.
**Gnaphalium purpureum*, L.
Emilia sonchifolia, DC.
Campanula canescence, Wall.—
**Exacum petiolare*, Griseb.—
E. pedunculatum, L.—
**Canscora decurrens*, Dalz.
Evolvulus alsinoides, L.
Lindenbergia urticæfolia, Lehm.—
**Vandellia brachiata*, Haines.—
**V. crustacea*, Benth.
**Lindernia parviflora*, Haines.
**Scoparia dulcis*, L.
**Nelsonia campestris*, Br.—
**Hemigraphis hirta*, T. Anders.
**H. latebrosa*, Nees. var *rupestris*, Clarke.—
Ruellia cernua, Roxb.
**Dædalacanthus nervosus*, T. Anders.
**D. purpurascens*, T. Anders.
**Barleria cristata*, L.
**B. strigosa*, Willd.—
Lepidagathis purpuricaulis, Nees.

Rungia parviflora, Nees.—
Justicia betonica, L. var. *ramoisissima*
J. simplex, Don.
**Dicliptera roxburghiana*, Nees.—
D. micranthes, Nees.
D. bupleurides, Nees.
**Andrographis paniculata*, Nees.
**A. echiodes*, Nees.
Ocimum gratissimum, L.
**Anisochilus carnosus*, Wall.
**Meriandra benghalensis*, Benth.—
**Nepeta hindostana*, Haines.
**Leucas procumbens*, Desf.—
Ajuga macrosperma, Wall.—
**Pilea microphylla*, Liebm.
**Sauromatum guttatum*, Schott.
Ariesema tortuosum, Schott.
**Typhonium trilobatum*, Schott.—
Cyperus distans, L.f.
**C. iria*, L.
**C. rotundus*, L.
Kyllinga cylindrica, Nees.
Mariscus sieberianus, Nees.
**Scleria hebecarpa*, Nees.—
**Heteropogon contortus*, Roem.
†*Themeda imberbis*, T. Anders.
**Pollinidium angustifolium*, Haines.
**Eragrostis ciliata*, Nees.—
E. gangetica, Steud.
**E. pilosa*, Beauv.
**Desmostachya cynosuroides*, Stapf.
**Sehima nervosum*, Stapf.—
**Cynodon dactylon*. Pers.
**Eleusine coracana*. Gaertn.
**E. ægyptica*, Desf.
**Sporobolus diander*, Beauv.—
**Perotis latifolia*, Ait.
Thysanolæna agrostis, Nees.—
Pennisetum orientale, Rich.
**Setaria glauca*, Beauv. var. *macrocarpa* F.B.I.—
**Amphilophis glabra*, Stapf. var. *hænkii* Hack.
Sorghum nitidum, Pers.—
Chrysopogon montanus, Trin.
**Dichanthium caricosum*, Haines.—
**Apluda varia*, Hack. *subsp. mutica*.
**A. varia*, Hack. *subsp. aristata*
Manisuris granularis, L.f.
**Rottboellia exaltata*, L.f.
**Mnesithea perforata*, Haines.
**Panicum psilopodium*, Trin.
**P. humile*, Nees.
**P. maximum*, Jacq.
P. trypheron, Schultz.
P. montanum, Roxb.
Oplismenus compositus, Beauv.—
**Paspalum scrobiculatum*, L.
Digitaria sanguinalis, Scop.
**D. sanguinalis*, Scop. var. *ciliaris*, J.D.H.
**D. royleana*, Prain.—
**D. pedicillaris*, Prain.—
**Alloteropsis cimicina*, Stapf.
**Saccharum spontaneum*, L.
Commelina obliqua, Ham.—
**C. suffruticosa*, Blume.—
**Aneilma nudiflorum*, Br.
**A. vaginalis*, Br.
**Cyanotis cristata*, Schultz.
Dioscorea belophylla, Voight.
D. hamiltonii. Hook.f.
†*D. tomentosa*, Heyne.
Zingiber casumnar, Roxb.
†*Z. capitatum*, Roxb. var. *elatum*, Roxb.—

Between 2,000 *and* 4,000 *feet*

†*Mollugo nudicaulis*, Lamk.
Abutilon polyandrum, W. & A.
**Vigna vexillata*, Benth.
**Smithia conferta*, Sm.—
Plumbago zeylanica, L.
**Melothria zehneroides*, Haines.
**Begonia picta*, Sm.
Knoxia brachycarpa, Bl.
†*Argostemma verticillatum*, Wall.
Rubia cordifolia, L.
**Oldenlandia brachiata*, Wight.
**O. herbacea*, Roxb.
**Hedyotis pinifolia*, H.f.
**Vernonia roxburghii*, Less.
V. divergens, Benth.
Blumea wightiana, DC.
B. jacquemontii, Hook.f.
Senecio nudicaulis, Ham.
†*Campanula colorata*, Wall.
Cephalostigma hirsutum, Edgew.
**Ceropegia hirsuta*, W. & A.
†*C. vincæfolia*, Hook.
Rhynchoglossum obliquum, Blume.
**Mitreola oldenlandioides*, Wall.
**Torenia cordifolia*, Roxb.
**Petalidium barlerioides*, Nees.
**Strobilanthes auriculatus*, Nees.
**Lepidagathis hyalina*, Nees.
Justicia diffusa. Willd. var. *orbiculata*, Clarke.
**Acrocephalus capitatus*, Benth.
**Geniosporum elongatum*, Benth.
†*Mentha piperata*, Linn.
Micromeria capitellata, Benth.
**M. biflora*, Benth.
Leucas lanata, Benth. var. *nagpurensis*, Clarke.
L. montana, Spreng.
Plectranthus ternifolia, Don.
Achyranthes bidentata, Blume.
Polygonum alatum, Ham.
**P. capitatum*, Ham.
**P. chinensis*, L. var. *ovalifolia*.
**P. chinensis*, L. var. *chinensis*.

**Amorphophallus bulbifer*, Blume.
Fimbristylis thomsoni, Bœch.
F. quinquangularis, Kunth.
Scleria lithosperma, Sw. var. *roxburghii*.
†*Chrysopogon gryllus*, Trin.
**Iseilema laxum*, Hack.
†*Cymbopogon cæsius* (Nees.) Stapf.
†*C. pendulous*, Nees ex Steud.
**Diectomis fastigiata*, H.B.K.
†*Pogonatherum crinitum*, Kunth.
†*Microstegium monanthum*, A. Camus.
Capillidium assimilis, Haines.
C. parviflora, Stapf.
Arthraxon ciliaris, Haines.
**A. lanceolatus*, Haines.
**Coix lachryma-jobi*, L.
†*Cyanotis barbata*, Don.
**Chlorophytum tuberosum*, Baker.
**Curculigo orchioides*, Gaertn.
**C. recurvata*, Dryand.
**Curcuma reclinata*, Roxb.
Globba bulbifera, Roxb.
G. racemosa, Smith.
**Kampferia rotunda*, L.
Musa sapientum, L.
Habenaria lawii, Hook. f.
**H. constricta*, Hook.f.
H. goodyeroides, Don.

Above 4,000 *feet*

Thalictrum foliosum, DC.
†*Polygala triphalla*, Ham. var. *glaucescens*, Wall.
**Polycarpœa corymbosa*, Lamk.
**Reinwardtia trigyna*, Planch.
Geranium ocellatum, Camb.
**Crotalaria prostrata*, Roxb.
Smithia ciliata, Royle.
Osbeckia chinensis, L. var. *parasnathensis*. *?*
Sonerilla tenera, Royle.
Anotis calycina, Wall.
Crepis japonica, Benth.
**Artemisia parviflora*, Roxb.
**A. caruifolia*, Ham.
**Wedelia wallichii*, Less.
**Siegesbeckia orientalis*, L.
†*Anaphalis contorta*, Hk.f.
Sonchus arvensis, L. var. typica
**Lobelia zeylanica*, L. var. *alligera*, Haines.
Cynoglossum denticulatum, A.DC.
Vandellia sessiliflora, Benth.
**Utricularia wallichiana*, Wight.
Justicia simplex, Don. var. *serpyllifolia*, Benth.
†*Leucas mollisma*, Wall.
Pouzolzia hirta, Haask.
Imperata arundinacea, Cyrill.
†*Pennisetum orientale*, Rich. var. *triflorum*, Stapf.
Colocasia antiquorum, Schott. var. *rupicola*, Haines.
C. fallax, Schott.
Alocasia fornicata, Schott.

ON *LIAGORA ERECTA* ZEH

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(With 14 Text-Figures)

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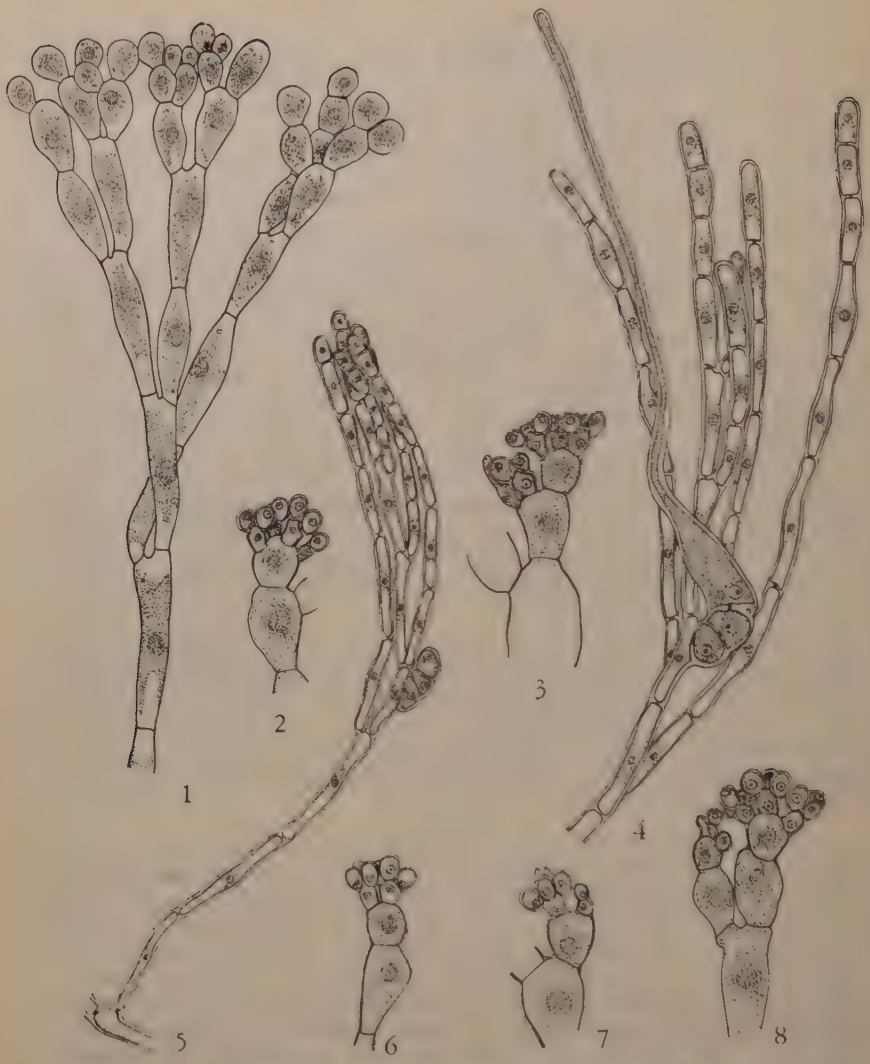
Liagora erecta Zeh was based on a specimen from the Madras Beach (Zeh, 1913, p. 268; Boergesen, 1937, p. 43). Fragments of this specimen are still available at the British Museum and also at the Botanical Museum at Berlin-Dahlem. This alga was again reported by Boergesen (1937, pp. 43–46) based on plants collected by Prof. Iyengar from Mahabalipuram (Seven Pagodas). The alga was later on collected repeatedly by Prof. Iyengar from the same locality and also from Covelong, a few miles south of Madras. Srinivasan (1946, pp. 270 and 275) has made some observations on the ecology of this alga at Mahabalipuram. Prof. Iyengar kindly placed his collections of the alga at the disposal of the author for the present study. Some of the material for this study was preserved in 4% formalin and the remaining in 60% alcohol.

The general habit and structure of the thallus including the antheridia and the carpogonial branches have been described in detail by Boergesen (1937). A detailed account of the sexual reproduction and the post-fertilization stages was, however, not given by him. The author made a study of these post-fertilization stages. These showed many interesting features which are described in detail below along with the other features of the alga.

The thallus is strongly calcified and is profusely and pinnately branched. The lower branches often reach a considerable length and are in turn ramified like the main axis, while in the younger portions of the thallus they do not show secondary ramification. The thallus is of the usual fountain-type seen in *Liagora*. There is a central medullary portion consisting of several longitudinal filaments which are compactly arranged. From these medullary filaments lateral branches or assimilatory filaments arise and these together go to form the cortical portion. The assimilatory filaments are repeatedly dichotomously branched, the number of furcations ranging from four to six (Text-Fig. 1). The lower cells are characteristically fusiform or barrel-shaped in fully developed condition, and the cells become gradually shorter and more rounded towards the periphery of the thallus. The distance between the furcations also gradually diminishes towards the periphery.

The alga is dicœcious. The antheridia are borne in clusters at the extremities of the assimilatory filaments. From the terminal cells of the assimilatory filaments, one to five or six antheridial mother-cells are formed. Each antheridial mother-cell bears one to four antheridia (Text-Figs. 2, 3, 6 to 8).



TEXT-FIGS. 1–8. *Liagora erecta* Zeh.—Fig. 1. An assimilatory branch, ×425. Figs. 2, 3, 6–8. Extremities of peripheral filaments with antheridia, ×1,000. Fig. 4. A fully developed carpogonial branch, ×800. Fig. 5. Early stage in the development of a carpogonial branch, ×550.

The carpogonial branches are developed as short lateral branches low down on the assimilatory filaments. These are formed generally on the younger portions of the thallus even before the assimilatory filaments have attained their full development (Text-Fig. 5). In this species, the carpogonial branches are borne commonly near the first and the second furcations (Text-Figs. 4, 5), or less frequently a little

higher up between the second and the third furcations. The carpogonial branches are characteristically much curved at the basal part (*cf.* Boergesen, 1937, p. 44, Fig. 26 *b*). They are usually three-celled, though four-celled carpogonial branches are not uncommon. It may be mentioned here that Boergesen observed only four-celled carpogonial branches and so he does not describe any three-celled carpogonial branches. Abnormalities, such as, aborting and vegetative proliferation of the carpogonial branch and forking of the trichogyne, were also noticed.

In the following account the author deals with the post-fertilization stages observed by him in three-celled carpogonial branches. The carpogonium is large as compared with the other cells of the carpogonial branch. It gradually tapers into a long trichogyne which projects appreciably above the tips of the assimilatory filaments (Text-Fig. 4). After fertilization, the protoplast of the basal part of the carpogonium is cut off from that of the trichogyne (Text-Fig. 10). The fertilized carpogonium then divides transversely into two approximately equal daughter-cells (Text-Figs. 11, 14). Of these two daughter-cells, the upper one takes part in the development of the gonimoblast filaments (Text-Figs. 9, 13). These gonimoblast filaments are profusely branched and bear carposporangia terminally (Text-Fig. 12). The lower daughter-cell does not take part in gonimoblast formation.

As the gonimoblast filaments are being formed by the upper daughter-cell, certain changes take place in the cells of the carpogonial branch. These cells now show denser contents and enlarge slightly. The protoplasmic connections between them gradually widen and finally a large fusion-cell is formed incorporating in it the lower daughter-cell of the fertilized carpogonium, the two sterile cells of the carpogonial filament and the supporting cell (Text-Figs. 9, 13, 14). The upper daughter-cell of the fertilized carpogonium from which the gonimoblast filaments are produced always remains distinct and can be easily distinguished at all the stages. The fusion-cell clearly shows grooves marking the limits of each of the several cells going into fusion (Text-Fig. 13).

The ripe cystocarp is a large sub-globular body composed of the densely aggregated gonimoblast filaments, surrounded by a well-developed 'involucrum' or protective envelope composed of long narrow incurved branched filaments. The involucral filaments begin to develop soon after fertilization. The initials of the involucral branches arise from the cells above and below the supporting cell (Text-Figs. 10, 11, 14). Rarely, however, the cells of the neighbouring filaments also produce them. These involucral branches grow up around the developing gonimoblast filaments from which they can be readily distinguished. In the earlier stages they have dense protoplasmic contents, becoming later almost colourless. Still later, the tips of the involucral branches also become characteristically attenuated and incurved (Text-Fig. 9). There is also a lateral displacement of the two groups of involucral filaments due to the enlargement of the fusion cell and the gradual evection of the developing gonimoblast, so that each group

TEXT-FIGS. 9–14. *Liagora erecta* Zeh.—Figs. 9–11, 13, 14. Post-fertilization stages leading to th
tion of a cystocarp, ×1,125. Fig. 12. A portion of the cystocarp showing carpospores, ×1,000.

comes to form one half of the protective investment round the developing gonimoblast.

Discussion

The genus *Liagora* has been studied by a number of authors (Butters, 1911; Boergesen, 1915 to 16, 1927; Kylin, 1930; Yamada, 1938; Levring, 1941; Abbott, 1945). Papenfuss (1946) in his masterly review of the Helminthocladaceous genera was the first to show the lacunæ in our knowledge of certain aspects of the life-history of *Liagora*, especially in the occurrence of a fusion cell and the development of the involucral filaments. Recently Desikachary (unpublished)* studied the post-fertilization stages in *Liagora maxima* Butters and clarified certain points raised by Papenfuss.

The details of development recorded here are somewhat at variance with those given by older workers (Butters, 1911, etc.), but are in general agreement with those of *Liagora maxima* as described by Desikachary. Desikachary has recorded a fusion-cell in *L. maxima* similar to the one described here for *Liagora erecta*. As far as the writer is aware, the only other record of the occurrence of a fusion-cell in *Liagora* is that of Kylin (1930) in *L. viscida* (Forssk.) C. Ag. Thus *L. erecta* becomes the third species in which a fusion-cell is formed. As Desikachary remarks in his unpublished paper, it would be interesting to know how many of the remaining species of *Liagora* show such a fusion-cell.

It has previously been reported in some species of *Liagora* that the involucral filaments take their origin from either the supporting cell or from the sterile cells of the carpogonial branch (*cf.* Hamel, 1930, p. 16; Abbott, 1945, p. 148). In other cases the exact nature of the origin of these filaments is not clear. Desikachary clearly observed in *Liagora maxima* that the involucral filaments arise from the cells of the assimilatory filaments immediately above and below the supporting cell and not from the supporting cell or the sterile cells of the carpogonial branch. The same is the case in *L. erecta* as is observed in the present study.

Liagora erecta agrees with *L. viscida* in possessing a fusion-cell. But it differs from *L. viscida* in having very well-developed involucral filaments, whereas no involucral filaments are developed in the latter. *L. erecta* agrees with *L. maxima* in having a fusion-cell and also well-developed involucral filaments. It agrees very closely with the latter in many other respects also. The agreement between *L. erecta* and *L. maxima* is so complete that one wonders whether they are not the same (*cf.* also Abbott, 1954, p. 148). This point can be settled only after a fresh examination of the type specimen of Zeh. If a fresh examination should show that these two species are identical, then the binomial *L. maxima* will be the valid name of the alga and the other, *L. erecta*, a synonym.

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* Dr. Desikachary of Saugar University kindly gave me his unpublished paper and figures for reference.

Summary

Post-fertilization stages of *L. erecta* Zeh from Mahabalipuram (Seven pagodas) near Madras are described in detail. The alga agrees with *L. maxima* in having a fusion-cell and also in the development of the involucral filaments from the vegetative cells above and below the supporting cell. There is a great resemblance between the two species in other respects also.

The writer wishes to express his great indebtedness to Prof. M. O. P. Iyengar for his kind guidance and advice in the present investigation, to Prof. T. S. Mahabale for kind facilities and encouragement and to Dr. T. V. Desikachary for his help and criticism and for permission to see his unpublished work on *L. maxima*.

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EMBRYOLOGY OF *TRICHOPUS ZEYLANICUS* GAERTN.

By A. Nagaraja Rao

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(With 75 Text-Figures)

(Received for publication on April 28, 1955)

The family Dioscoreaceæ is tropical or sub-tropical, mostly consisting of creeping and erect herbs. Hooker (1894) records only two genera *Dioscorea* and *Trichopus*, in Ceylon and South India. *Trichopus* is placed by Engler and Prantl (1897) in the second tribe Stenomerideæ of the family. *T. zeylanicus* is a small erect, rigid perennial twiner. The flowers are bisexual and fascicled at the base of the leaf. Previous literature on the embryology of this family has been reviewed by Smith (1916), Schnarf (1931) and Nagaraja Rao (1953). The present study concerns the embryology of *T. zeylanicus*.

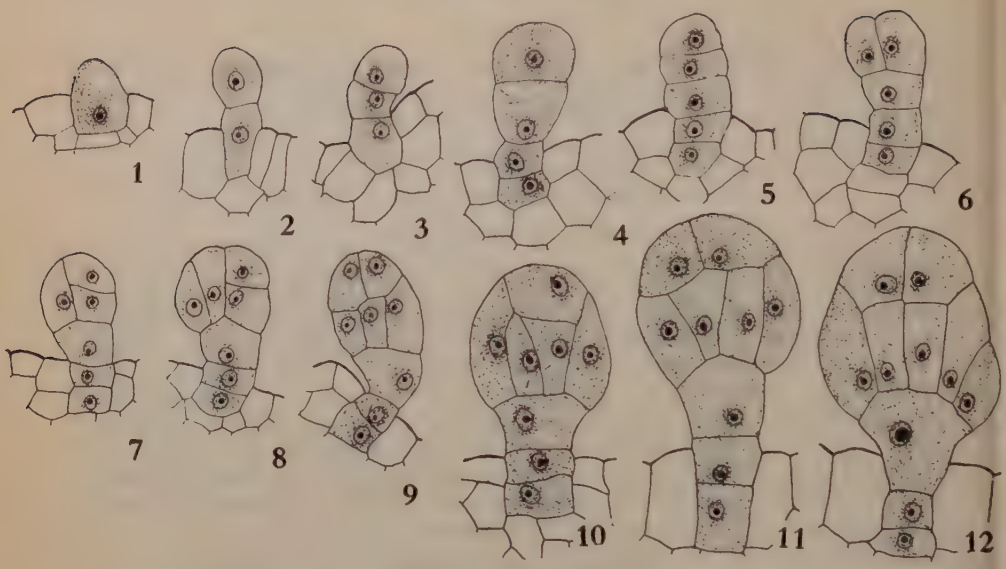
Material and Methods

The material was collected in the vicinity of Peradeniya gardens, Ceylon, and fixed in formalin-acetic-alcohol. Dehydrating and embedding was done in the customary way and sections were cut at a thickness of 10–20 microns. Much difficulty was experienced in cutting the mature seeds due to the deposition of hemicellulose in the endosperm tissue. The seed coat also included thick depositions of tannin. The sections were stained in Heidenhain's hæmatoxylin with erythrosin and eosin as counter-stains. Whole mounts were prepared to study the nature of pollen grains and the endosperm.

Observations

Glands.—The epidermal cells on the wall of the young ovary produce a number of multi-cellular glands. To begin with an epidermal cell grows out in the form of a papillate protrusion (Fig. 1) and undergoes a transverse division to form an upper and a lower cell (Fig. 2). The lower gets embedded in the epidermis and later on both of them undergo one more transverse division to produce a four-celled structure (Figs. 3, 4). The lower two cells form the stalk of the gland, whereas the uppermost cell enlarges and divides either transversely (Fig. 5) or vertically (Fig. 6). Further vertical and transverse divisions take place in the upper cell and a gland is formed with 8–10 cells (Figs. 7–12). Such glands are arranged in regular series on the wall of the ovary.

Organogeny.—Vertical sections through the fascicles of young flowers show that the bract is a lateral outgrowth in whose axil arises the floral primordium (Fig. 13). This grows into the floral receptacle and pedicel (Fig. 14). The bracteole is absent and the floral parts arise in regular acropetal succession on the floral receptacle (Figs. 15–18).

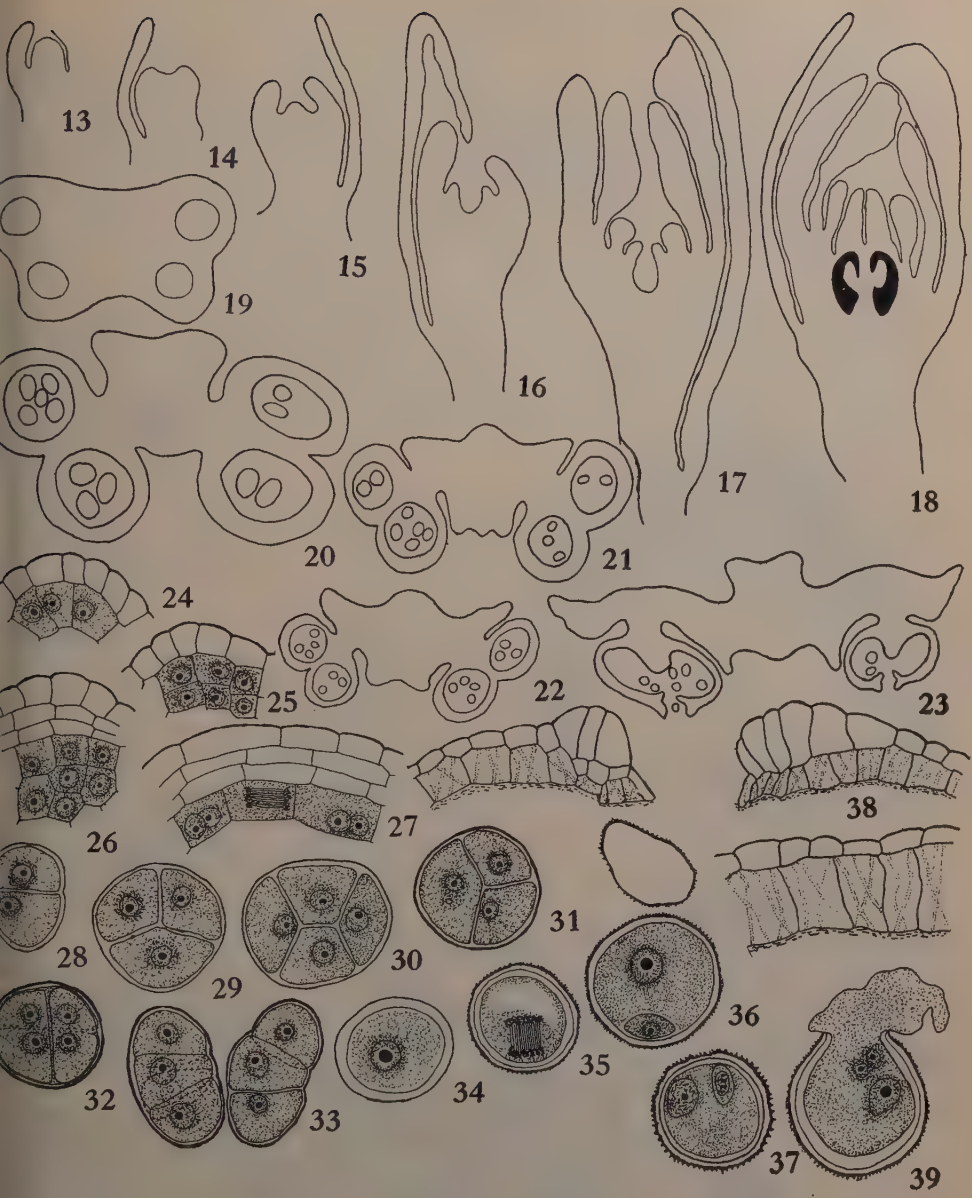


TEXT-FIGS. 1–12. Stages in the development of glands, × 450.

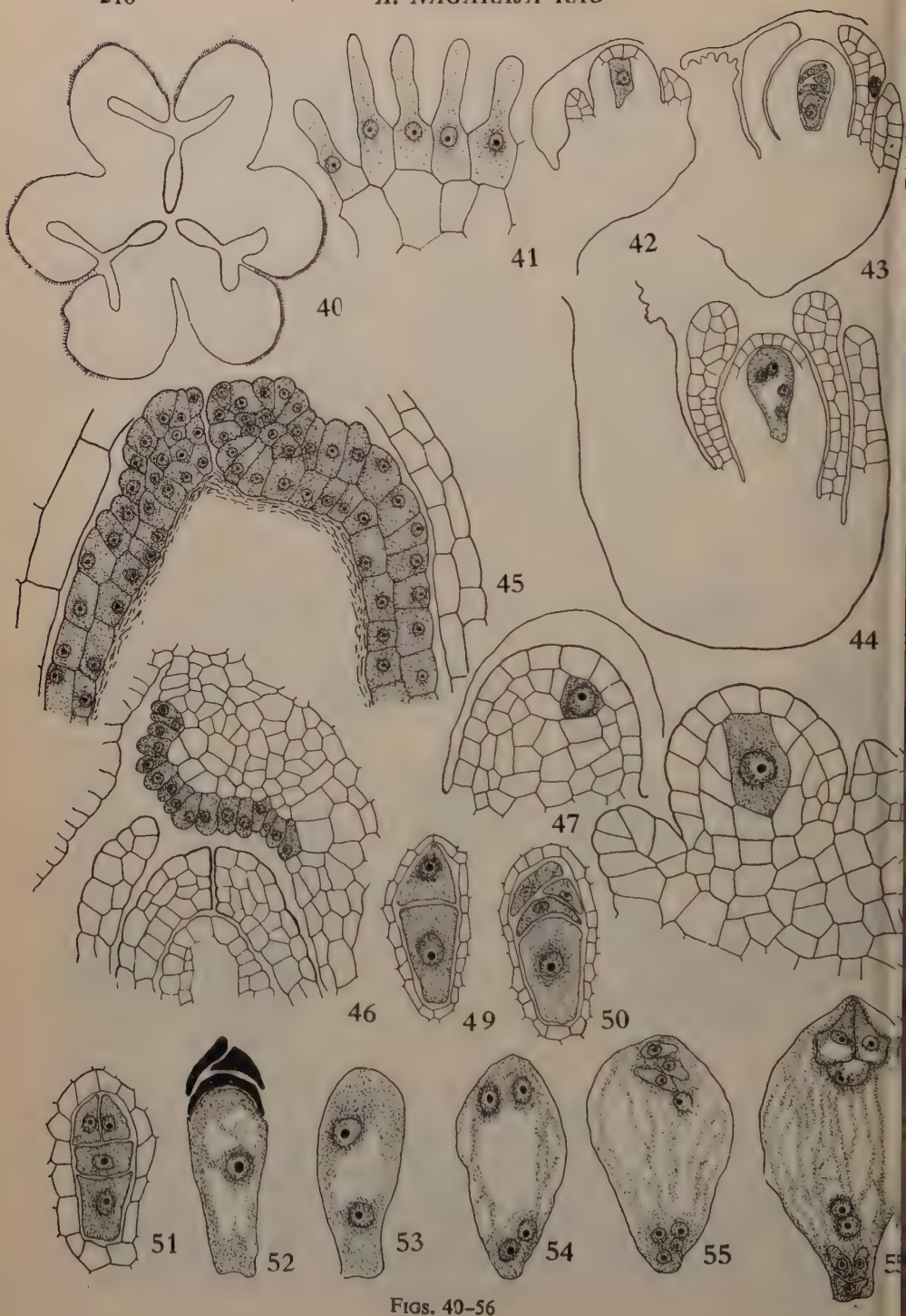
Microsporogenesis and Male Gametophyte.—The six stamens are arranged on the bases of the perianth lobes. The anthers are short and subsessile, each with a connective and four locules (Fig. 19). The connective soon differentiates in the form of a disc (Fig. 20, 22). Later it broadens and outgrows the locules and as a result the latter bend downwards and show the introrse mode of dehiscence (Fig. 23).

A transverse section of the young anther lobe shows a plate of three to four hypodermal archesporial cells in each lobe (Fig. 24). They divide periclinally to form the primary parietal and the primary sporogenous layers (Fig. 25). The parietal layer undergoes further periclinal divisions to form the wall of the anther while the sporogenous cells after undergoing a few more divisions become converted into spore mother cells (Fig. 26). The outermost layer is the epidermis, next comes the endothecium, then a middle layer and finally the glandular tapetum whose cells become binucleate (Fig. 27). The microspore mother cells undergo the usual reduction divisions to form the dyads (Fig. 28) and later on tetrads of microspores. Separation of microspores takes place by cell plate formation and they are tetrahedral (Fig. 29), isobilateral (Fig. 30), decussate (Figs. 31, 32) or linear in their arrangement (Fig. 33).

The young microspore has a prominent nucleus situated in the centre and is surrounded by dense cytoplasm (Fig. 34). Owing to the formation of a vacuole the nucleus moves to the periphery and divides (Fig. 35) to form a large tube nucleus and a small generative cell (Fig. 36). The pollen grain at the time of shedding is a two-celled, monocolpate structure with a thick spinulate exine and a thin intine (Fig. 37) as in *Dioscorea oppositifolia* (Nagaraja Rao, 1953). In the mature anther



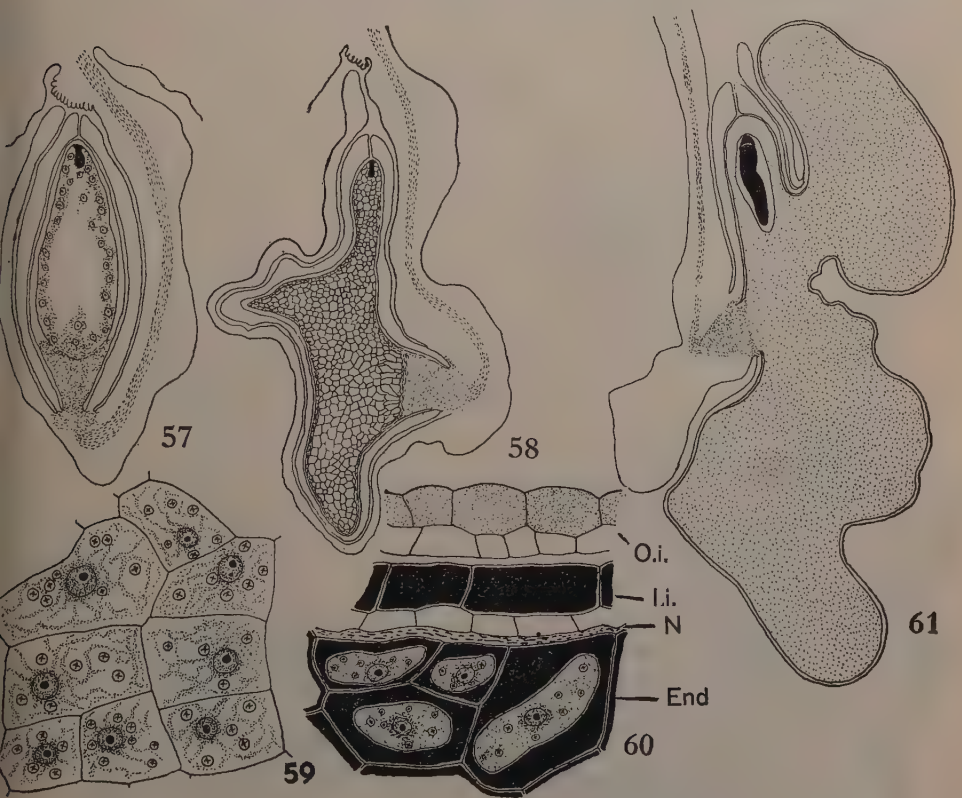
TEXT-FIGS. 13–39. Figs. 13–18. Stages in the development of the flower, ×450. Figs. 19–23. T.s. anther to show the development and broadening of the disc-like connective and also the mode of dehiscence. Fig. 19, ×180, Fig. 20, ×100, Fig. 21, ×60. Figs. 22, 23, ×50. Fig. 24. Part of anther showing archesporial cells, ×470. Fig. 25. Primary parietal and sporogenous layers, ×470. Figs. 26, 27. Stages in development of anther wall, ×450. Fig. 28. A dyad, ×450. Figs. 29–33. Tetrahedral, decussate, isobilateral and linear tetrads, ×450. Fig. 34. Uninucleate microspore, ×450. Fig. 35. Division of microspore nucleus, ×450. Fig. 36, 37. Two-celled pollen grains, ×450. Fig. 38. Portion of mature anther to show stomium and fibrous endothecium, ×180. Fig. 39. Pollen grain germinated *in situ*. Note the male nuclei, tube nucleus and pollen tube, ×450.



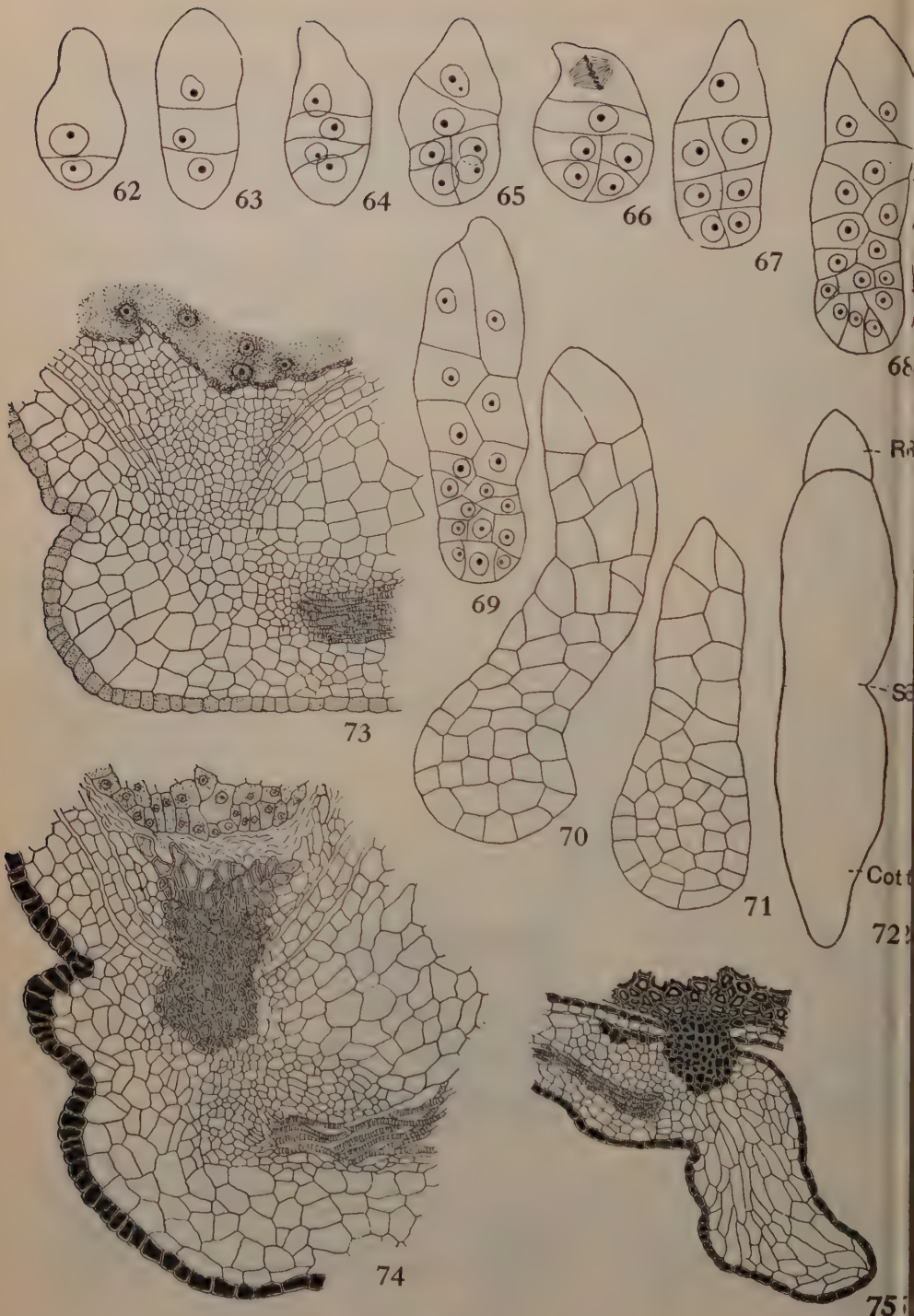
FIGS. 40–56

TEXT-FIGS. 40–56. Fig. 40. Stigmatic lobes, ×35. Fig. 41. Unicellular hairs on the stigmatic lobes, ×180. Figs. 42–44. Stages in the development of the anatropous ovule, ×225. Fig. 45. Micropylar region to show the inner integument, ×225. Fig. 46. Micropylar region to show the obturator, ×100. Fig. 47. L.s. young nucellus showing primary archesporial cell, ×470. Fig. 48. Megaspore mother cell, ×470. Fig. 49. Dyad, ×450. Figs. 50–51. Linear and T-shaped tetrads, ×450. Figs. 52–54. Uninucleate, binucleate and four-nucleate embryo sacs, ×450. Fig. 55. Eight-nucleate embryo sac before organisation, ×450. Fig. 56. Mature embryo sac, ×450.

the tapetum and the middle layer completely disorganise; only the epidermis and the endothecium persist and the latter develops characteristic fibrous thickenings. The epidermal cells on either side of the line of dehiscence enlarge conspicuously and constitute the stomium (Fig. 38). In a few anther locules the pollen grains had germinated *in situ*. One such pollen grain with a well-developed tube is shown



TEXT-FIGS. 57–61. Fig. 57. Ovule showing peripherally placed endosperm nuclei, ×100. Fig. 58. Same at a later stage to show cellular endosperm, ×50. Fig. 59. A few of the endosperm cells enlarged, note the starch grains, ×450. Fig. 60. Endosperm cells in mature seed. *I.i.*, inner integument; *O.i.*, outer integument; *N*, nucellus; *End*, endosperm, ×180. Fig. 61. L.s. seed to show mature embryo, the irregular growth of the ovule and the endosperm tissue, ×24.



FIGS. 62–75

TEXT-FIGS. 62-75. Figs. 62–71. Stages in the development of the embryo, ×500. Fig. 72. Outline of mature embryo showing cotyledon, *cot*, cotyledon; *st*, stem tip; *Rc*, root cap. Fig. 73. Chalazal portion of ovule enlarged to show hypostase and free nuclear endosperm, ×140. Fig. 74. Same at a later stage showing cellular endosperm, hypostase, integuments and the thickening in the funicular strand, ×140. Fig. 75. Same in the mature seed, note the development of small chalazal wing, ×40.

in Fig. 39. This precociously germinated pollen grain shows a large tube nucleus and two male nuclei.

Megasporogenesis and Female Gametophyte.—The ovary is inferior, tricarpellary, trilocular, and bears one to two anatropous, crassinucellate bitegmic ovules in each locule, arranged on axile placenta. The stylar lobes are six in number and are incurved (Fig. 40). On the outer surface of these there develop a number of unicellular glandular hairs (Fig. 41). The wall of the ovary is many layered, consisting of loosely arranged parenchymatous cells with sparse cell contents.

The nucellus consists of a mass of thin-walled parenchymatous cells. The ovule appears as a conical outgrowth on the placenta (Fig. 18) and the two layered inner integument develops earlier than the two layered outer integument (Figs. 42, 44). Both the integuments develop further and participate in the formation of the micropyle (Fig. 46). In this region, however, the inner integument becomes three to four layered (Figs. 45, 46) and the cells are glandular with prominent cell contents. In the micropylar region the cells of the funiculus divide very actively and organise into an obturator at the mature embryo sac stage. The cells of the outermost layer of the obturator are glandular and show prominent cell contents (Fig. 46).

There is usually a single hypodermal archesporial cell (Fig. 47). This does not divide further to produce parietal cells but functions directly as the megaspore mother cell (Fig. 48). The latter divides twice to form the dyad (Fig. 49) and later on the tetrad which may be linear (Fig. 50) or 'T'-shaped (Fig. 51). The chalazal megaspore functions and the nucleus of the functioning megaspore divides thrice to form an eight-nucleate embryo sac of the Polygonum type (Figs. 52–56) as in *Dioscorea oppositifolia* (Nagaraja Rao, 1953). The mature embryo sac is broad above, and narrows downwards to form a pouch-like chalazal end in which the antipodal cells are situated. The synergids are hooked and usually the micropylar polar nucleus migrates downwards and meets the chalazal polar nucleus very near the antipodal region (Fig. 56). The two and four-nucleate embryo sacs are surrounded by six to eight layers of nucellar cells. The antipodal cells degenerate soon after fertilization and very rarely persist till the egg undergoes the first division. After fertilization the antipodal end of the embryo sac elongates and finally extends to the base of the ovule where it comes in contact with the hypostase (Fig. 57).

Endosperm.—The primary endosperm nucleus divides and produces a number of free endosperm nuclei that are placed peripherally by the formation of a central vacuole (Fig. 57). After the formation of a large number of endosperm nuclei cytokinesis sets in, resulting in the formation of a cellular endosperm (Fig. 58). The endosperm

cells are large with prominent nuclei, dense cytoplasm and plenty of oil globules (Fig. 59). In the mature seed the outer wall layers of the endosperm become thick and hard owing to the heavy deposition of hemicellulose (Fig. 60). The endosperm persists in the mature seed (Fig. 61) as in *Dioscorea oppositifolia* (Nagaraja Rao, 1953).

Embryo.—The first division of the fertilized egg is usually transverse (Fig. 62) as in *Tamus communis* (Solms-Laubach, 1878) and *Dioscorea oppositifolia* (Nagaraja Rao, 1953) resulting in the formation of a two-celled proembryo. Further stages in the development of the embryo are shown in Figs. 63–72. The mature embryo is elongated and monocotyledonous with a terminal cotyledon, a lateral stem tip and the root tip covered by the root cap (Fig. 72).

The mature seed.—The mature seed is oblong, rugose, grooved dorsally and dark brown in colour. The testa is formed from the outer integument whose outer epidermis contains dense cytoplasm. The inner layer is made up of thin-walled cells. The tegmen is formed by the inner integument; its outer layer consists of elongated cells densely filled with tannin while the inner consists of thin-walled cells (Fig. 60).

During the development of the seed the cells of the chalazal region gradually become elongated (Fig. 57). The vascular strand in the funiculus ends at the base of the chalaza. At the fertilization stage a few cells at the chalazal end become conspicuous by their dense cell contents (Fig. 73); later on they round off, and their cell walls become thickened (Fig. 74). This tissue is the hypostase, and as a result of its formation the chalazal end of the embryo sac ceases to grow further. The seed, however, grows in all directions and even above the micropylar region (Fig. 61). This type of growth brings the chalaza and micropyle nearer. The hypostase persists in the mature seed (Fig. 75) as in *Dioscorea oppositifolia* (Nagaraja Rao, 1953) and the cells that are situated below this region elongate and form a wing. The cells of the outermost layer of the wing are filled up with dark cell contents.

Summary

The floral parts originate in acropetal succession. Multicellular stalked glands are present on the epidermal wall of the ovary.

The wall of the anther consists of three layers of cells external to the tapetum. The tapetal cells are glandular and binucleate and the endothecium is fibrillar. Dehiscence is longitudinal. The microspores are arranged in an isobilateral, linear or decussate manner. The mature pollen grain is two celled.

The ovary is inferior and trilocular with one or two anatropous bitegmic crassinucellate ovules arranged on an axile placenta.

The development of the embryo sac is of the Polygonum type. The synergids are hooked and the antipodals are organised as cells.

The endosperm is free nuclear to begin with but later becomes cellular. It persists in the mature seed. The cells store fats and show plenty of hemicellulose deposition.

The development of the embryo and the structure of the seed coat have been described.

My sincere thanks are due to Prof. P. Maheshwari for going through the manuscript and making valuable suggestions; to Prof. L. N. Rao for kind encouragement and guidance. I am also thankful to my friend Shri M. R. Anandaramaiah, Curator, Lalbagh, Bangalore, for having collected the material. To the authorities of the University of Mysore I am grateful, for the award of a research fellowship.

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* Solms-Laubach, H. 1878. Uber monocotyl Embryonen mit Scheitelburtigen Vegetationsponkt. *Bot. Ztg.*, **36**: 65–74, 81–93.

* Not seen in original.

ON THE OCCURRENCE OF *NELUMBIUM* IN THE TERTIARY OF ASSAM

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Birbal Sahni Institute of Palæobotany, Lucknow

(Received for publication on April 25, 1955)

Introduction

In 1947 I published a short preliminary note about a small collection of fossil plants made by Sir Cyril S. Fox " from Eocene beds at 500 yards south of Damalgiri Bungalow (25° 32′ N: 90° 7′ E), Garo Hills". Most of the specimens were so fragmentary that only a few plant species could be recognised. The recognisable species have recently been described by me (Lakhanpal, 1954).

In the same collection are a number of impressions which can be ascribed to the genus *Nelumbium*, although due to the insufficiency of preserved data it is not possible to assign them to any species. These remains form the subject-matter of the present paper.

Description

Order .. Ranales
Family .. Nymphæaceæ
Genus .. *Nelumbium* Juss.

Nelumbium sp.

(Plate VIII, Figs. 1–3; Plate IX, Fig. 4)

There are half a dozen incomplete impressions of leaves and one of a rhizome with roots attached. The lamina is not preserved in any of the leaf impressions owing perhaps to its being rotted away before fossilisation. Each specimen consists of a central circular impression of the petiolar region from which the primaries radiate out (Fig. 4). The diameter of the petiolar region is 1·2 to 1·8 cm. The maximum preserved length of the primaries is 11·5 cm. Their average width is 2·5 mm. By inference the number of secondaries in each leaf seems to be twenty. Secondaries are very slender, come out of the primaries at about 80°, and run straight for short distances towards the adjacent primaries. The rhizome (Fig. 2) is about 1·25 cm. in diameter. At the node a number of roots with root hairs come out of the rhizome.

Discussion

The identification of these impressions is rather difficult, especially in the absence of the lamina. But the central circular area of the petiole with radiating primaries and slender remains of finer veins indicate

affinity with the leaves of the fresh-water lotus, *Nelumbium*. In some specimens small circular or oval scars are visible in the central circular area (Fig. 1). They most probably represent the lacunar cavities of the petiole. The impression of the rhizome (Fig. 2) giving out a number of roots with rootlets strongly suggests its resemblance with the rhizome of the living *Nelumbium* (Fig. 3). Endo has given a figure of *Nelumbo nipponica* (Endo, 1934, Pl. XXXVII) which very much resembles one of the present specimens (Fig. 4). Endo's specimen is, however, bigger and better preserved.

Fossil records of *Nelumbium* occur right from Cretaceous up to Pleistocene. It has been reported from southern and western North America, Greenland, central and western Europe, Russian Far-East, northern Africa, Japan and India. A critical summary of the fossil record was given by Seward in 1935. Recently a more up-to-date account has been given by Puri (1950) who has described the first Indian fossil *Nelumbium* (as *Nelumbo nucifera* Gartn.) from the Pleistocene of Kashmir. The present fossil is a record from the early Tertiary rocks of India.

Living *Nelumbium* is a well-known fresh-water plant represented by two closely allied species, *N. speciosum* Willd. and *N. luteum* Willd. *N. speciosum* is found from southern Japan to northern Australia, India, Ceylon and reaches as far west as the Caspian Sea. *N. luteum* ranges from Ontario to Michigan, Florida and Louisiana and southward to the West Indies and Brazil. As opined by Berry (1917) this plant ought to have had a long geological history during which the ancestral species occupied areas intervening its present wide apart extremities of distribution. This view has been supported by the fossil record as mentioned above. The present occurrence adds another evidence in support of this view.

Collection.—Syntypes, Nos. GH 24, GH 25 and GH 27 kept in the Birbal Sahni Institute of Palæobotany museum.

Summary

The presence of *Nelumbium* in the Tertiary of Assam is recorded on the basis of a few impressions of leaves and a rhizome found in a collection from the Eocene beds near Damalgiri (25° 32′ N: 90° 7′ E). Due to the insufficiency of available data it is not possible to identify the plant specifically.

The present record furnishes another evidence in support of the view that *Nelumbium* ought to have had a long geological history.

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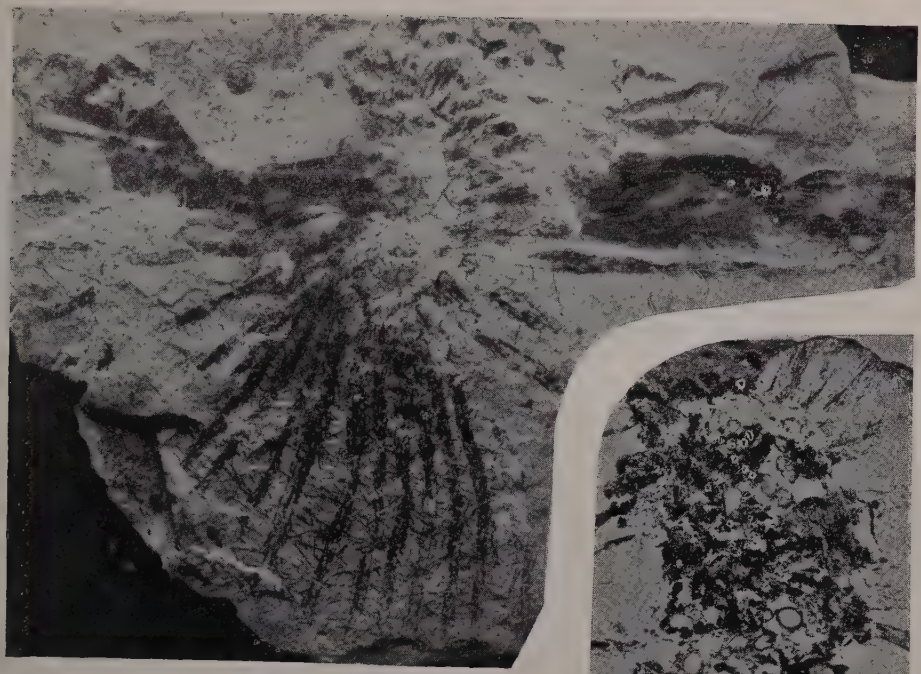
EXPLANATION OF PLATES

FIGS. 1–3. Fig. 1. *Nelumbium* sp. Impressions of central petiolar regions showing circular or oval outlines of the lacunar canals of the petioles seen transversely. No. GH 27, ×1½. Fig. 2. *Nelumbium* sp. Roots coming out of the node of a rhizome. No. GH 24, ×1. Fig. 3. *Nelumbium speciosum* Willd. A piece of the rhizome of the living *Nelumbium* showing the nodal region, ×1.

FIG. 4. *Nelumbium* sp. Primaries radiating from the central petiolar region. Secondaries also visible at a few places. No. GH 25, ×1.



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ON *DISCELLA CEDRELAE* RAMAKR. T. S. AND K.

By C. V. Subramanian and K. Ramakrishnan
University Botany Laboratory, Madras-5

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Discella cedrelæ was described by Ramakrishnan, T. S. and K. (1950) on living leaves of *Cedrela toona* Roxb., collected from Sim's Park, Coonoor, Nilgiris. In the course of a study of the Sphæropsidales, we had occasion to examine a fragment of the type collection (Herb. M.U.B.L. No. 740). Our study of the type material indicates that there is little to alter in the description of the fungus given by the authors (Ramakrishnan, T. S. and K., 1950, p. 110, Fig. 15), except for the fact that the pycnidium is described as subepidermal but figured as sub-cuticular (Fig. 15 *a*, *b*). Indeed, our examination of the type specimen confirms that the pycnidium is sub-cuticular as figured by the authors. The main purpose of this paper is to examine whether the assignment of the fungus to the genus *Discella* by the authors is valid.

The genus *Discella* was established by Berkeley and Broome (1850) with five species, of which the first *D. carbonacea* (Fr.) Berk. and Br. (Berkeley and Broome, 1850, p. 377) may be considered the type species. Berkeley and Broome's description of *D. carbonacea* and also their description of the genus *Discella* itself, indicate that their fungus is typically excipulaceous in structure. Indeed, "the chief mark of the Excipulaceæ is that the excipulum is open almost from the first, or else the upper part of the pycnidium vanishes quite early, leaving the basal portion, which contains the spores, in the shape of a cup, saucer or plate" (Grove, 1937, p. 125). In *D. carbonacea*, as described by Berkeley and Broome (1850) and later by Grove (1937), the pycnidium is at first complete above and irregular in outline. Later, it gradually disappears from the centre to the periphery as the epidermis ruptures and ultimately leaves a saucer-shaped cavity filled with the spores of the fungus.

It would be obvious from the above facts that *Discella cedrelæ* is not congeneric with the type species of *Discella*, *viz.*, *D. carbonacea*. The pycnidium of *D. cedrelæ* is sub-cuticular and is covered above by a layer of dark coloured fungal cells, forming a definite wall. This wall is not evanescent. The pycnidium, moreover, is flat below, the entire sporogenous stratum being parallel to the epidermal cells of the host tissue. It is never saucer- or cup-shaped. It is, therefore, clear that the fungus cannot be assigned to the Excipulaceæ.

On the other hand, the structure of the fungus indicates that it is a member of the Leptostromaceæ-Phæodidymæ. It agrees very closely with the generic description of *Didymochora* Hœhnel which is as follows:

"Stromata minuta, depressa, sub-cuticularia, uniloculigera; contextu parenchymatico carbonaceo; supra unistratoso, basi parenchymatico; sporulæ biloculares coloratæ, singulæ e stratu colorato efformatæ" (Saccardo, 1931, p. 514). Accordingly, we are now transferring *Discella cedrelæ* to the genus *Didymochora* Hœhnel. The only species of *Didymochora* so far known is the type species, *viz.*, *D. betulina* Hœhnel (collected on leaves of *Betula* sp. from Austria) for which a specific description was not given by Hœhnel and hence details of spore measurements, etc., are not available (Saccardo, 1931, p. 514). The type material has not been available for study. It is, therefore, not possible to state if our fungus is the same as *Didymochora betulina*. This fact coupled with the occurrence of the present fungus on an entirely different and unrelated host leads us to provisionally consider it a separate species under *Didymochora* as

Didymochora cedrelæ (Ramakr., T. S. and K.) Subram. and Ramakr. comb. nov.

Basinym: *Discella cedrelæ* Ramakr., T. S. and K., 1950, in *Proc. Indian Acad. Sci.*, B, **32**: 110, Fig. 15.

Type collection: on living leaves of *Cedrela toona* Roxb. (Meliaceæ), Sim's Park, Coonoor, Nilgiris (Madras State), October 9, 1947, coll. T. S. Ramakrishnan, Herb. M.U.B.L. No. 740, ex Herb. Government Mycologist, Coimbatore.

Summary

On the basis of a critical study of the type specimen of *Discella cedrelæ* Ramakr., T. S. and K. on *Cedrela toona* Roxb., the fungus is transferred to the genus *Didymochora* Hœhn. (Leptostromaceæ-Phæodidymæ) as *Didymochora cedrelæ* (Ramakr., T. S. and K.) Subram. and Ramakr.

We are grateful to Shri T. S. Ramakrishnan for kindly sending us a fragment of the type material of *Discella cedrelæ*.

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FOLIAR CALCIUM OF TEAK

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Introduction

Most problems of forest ecology are intimately connected with forest soil fertility. The importance of the utilization of mineral nutrients by the forest stands has been recognised as an effective means of soil fertility. The minerals drawn from the sub-soil region are in due course returned to the soil surface by leaf-fall and subsequent decomposition. Of the various parts of the trees that contribute to the nutrient capital, the leaves form by far the largest source. For this particular reason the study of forest litter is important.

The technique involved in the study of foliar ash is very simple, but the results throw light on problems connected with tree nutrition, crop yield, soil fertility, site quality, forest quality classes, soil climate and a number of allied problems, as can be judged from the works of Bard (1945), Chandler (1939 and 1941), Coile (1937), Garstka (1932), McHargue and Roy (1932), Lundegårdh (1934), Misra and Siva Rao (1948), Puri (1950), Puri and Gupta (1950 and 1954). Besides, in the absence of a sound knowledge of the physio-ecological behaviour of the species most workers have to be satisfied with timid interpretation of their field data. Although in a way the interpretation of field data can in certain cases be supplemented by soil analysis, nevertheless, Lundegårdh (1951) pointed out that " only with complementary leaf analysis do field experiments acquire a scientific value, chemical soil analysis, in my experience cannot compete with leaf analysis ". This is due to the variations in the reproduction of field results and unsatisfactory sampling methods. Earlier, Lundegårdh (1938) initiated work on triple analysis which included the plant, the soil and the sub-soil. Subsequently it has been found that the results obtained by plant analysis alone provided sufficient information and additional studies on soil and sub-soil were in most cases not so necessary.

From the observation of the field behaviour of teak and from the analysis of teak soils, it has been indicated (Bhatia, 1954) that teak distribution closely follows calcareous soils. Besides, of all the minerals present in the leaves, " the influence of calcium outweighs that of all the other bases combined. This is owing in part to the relatively large amounts of calcium present, as well as to the nature of cation" (Chandler, 1939). The study of foliar calcium becomes imperative for the reasons indicated above.

The role of calcium in the plant is not very clearly understood. Most workers believe that it counteracts the ill-effects of acids produced as bye-products in the metabolic activities of the plants. Further it has

been stated by Sorokin and Srumer (1929), that in pea, "shortage of calcium results in the decreased amount of cytoplasm and the failure of the nuclei to divide mitotically". Albercht (1941) found an increase in the percentage germination when calcium was applied as a fertilizer and the increase was more than when complete fertilizers were applied. He has indicated that calcium must be related to its present role as a nutrient and the effect could not be ascribed to the changes in soil reaction. Hamilton (1930) observed that when teak grows on soils in which lime has been leached out it often has a thin bark which splits leaving the wood exposed.

The role of calcium in the soil is more clearly understood. Calcium in soil affects profoundly certain soil characteristics, like pH, the population of soil micro- and macro-organisms, the type of humus and physical characteristics and aids in neutralising the organic acids produced during the decomposition of litters.

The study of this element becomes all the more important, when we consider, that each of the "soil cation has its own role, which cannot be taken up by another, even closely related in the Periodic system—calcium likewise cannot be replaced by any of the alkaline earth elements" (Maximov, 1938) and the variation in the uptake of the amount of any element is specific, making generalisations invalid.

Chandler (1941) has shown that below pH 4·5 conditions are unfavourable for the absorption and the accumulation of calcium. Hoagland and Arnon (1941), however, have pointed out that in acidic soils good growth of plants may be related to the high calcium supplying capacity. It would appear, therefore, that the availability of calcium depends upon a number of factors.

Lutz and Chandler (1946) quoting the works of Ramann (1890) and Morosov (1928) observed that the maximum nutrient uptake by most forest trees depends upon age, and that the maximum nutrient requirement of a forest stand comes in early of middle life and this requirement decreases with increasing age. The failure in plantations might be related to the inability of the soil to make available sufficient nutrients at this critical stage. Under such conditions forest trees do not manifest abnormal growth in the early stages but with advanced age very little progress is made after the pole-wood stage.

Puri and Gupta (1954) recently working on the seasonal variations of the foliar nutrient of 10 forest trees at Dehra Dun, U.P., found that in teak there was an increase in the amounts of calcium from the bud opening stage but towards leaf-fall there was a decrease. Most information on foliar calcium has been derived from Puri and Gupta's (1954) work on exotic teak at Dehra Dun.

Keeping in view some of the above considerations an attempt has been made to observe the behaviour of calcium with regard to the native teak at Sagar. Investigations on the following lines have been carried out:—

1. Variation in the amounts of foliar calcium with respect to soil pH and exchangeable calcium in the soil.

2. Variation in the uptake as affected by age.
3. Seasonal variation of foliar calcium in teak.

Method

Leaf samples were ashed in a muffle furnace at 600° C. Calcium was determined by the usual oxalate method from the hydrochloric acid extract (Loomis and Shull, 1933). The results are expressed as percentage of the oven-dry material.

Presentation of Data—Plant and Soil Analysis

The data are presented in Tables I–III.

Table I

Variation in the Amounts of Foliar Calcium with respect to Soil pH and Exchangeable Calcium of the Soil

Locality	Soil		Leaf		Remarks
	Exch. CaO %	pH	Ash %	CaO %	
Sagar Division—					
1 Ramna ..	0·34	6·95	9·24	2·49	Collected before flowering from midheight when leaves were mature
2 do ..	0·41	6·50	8·96	2·18	
3 Chatera ..	0·86	7·05	8·47	2·07	
4 Rahatgarha ..	0·37	6·45	10·01	1·94	
5 do ..	0·37	6·45	10·27	2·68	
6 Hirapur ..	0·58	6·83	8·00	2·00	
7 do ..	0·61	6·50	13·01	2·80	
8 do ..	0·38	6·00	12·19	3·90	
Nimar Division—					
9 West Kalibhet ..	3·44	7·50	14·89	2·85	Collected during flowering, later than the foregoing
10 do ..	1·85	7·45	16·16	3·43	
11 do ..	0·56	6·50	13·52	2·91	
South Chanda Division—					
12 Allapalli (Base of Bhimaram)	0·56	7·00	10·85	2·22	Collected as in Sagar division, but leaves were heavily attacked, by teak defoliator (14–15)
13 do (Compt. 76—A)	0·23	6·00	10·46	2·80	
14 do ..	0·23	6·00	8·47	1·80	
15 Compartment No. 9	0·84	6·20	7·08	1·96	
16 Bhimaram top	0·49	6·50	17·24	3·69	
17 Mixed forest ..	0·39	6·20	9·70	1·97	

TABLE II

Variation in the Uptake as Affected by Age

No.	D.B.H	Ash percentage	Calcium percentage	Remarks
1	Sapling	8·88	1·60	The leaf samples were collected from trees growing at the local Patharia forest on the same soil, at the same stage of seasonal growth.
2	do	10·33	1·79	
3	1½"	10·85	2·35	
4	2½"	10·45	1·68	
5	3"	11·74	2·52	
6	4½"	13·95	3·09	
7	6½"	10·69	2·22	
8	8½"	10·96	2·01	
9	10½"	10·79	2·15	
10	11"	10·86	2·68	
11	12"	11·81	2·61	
12	14"	10·54	2·14	

TABLE III

Seasonal Variation of Foliar Calcium in Teak

Date	Trees	Ash %	CaO %	Avg. ash %	Avg. CaO %	Remarks
15th July 1953 ..	1	9·62	1·42			Approx. age of the trees are 1 = 25 years, 2 = 32—35 years, 3 = above 72—75 years. Leaves collected from the 3rd internode
	2	8·15	1·82	8·91	1·65	
	3	8·96	1·72			
2nd August 1953 ..	1	10·69	2·21			
	2	9·18	2·13	10·14	2·32	
	3	10·54	2·62			
17th August 1953 ..	1	11·73	3·01			
	2	10·71	3·31	10·88	2·82	
	3	10·19	2·15			
5th September 1953	1	12·80	3·67			
	2	13·68	2·89	12·29	3·11	
	3	10·40	2·78			
5th October 1953 ..	1	11·19	2·51			
	2	13·14	2·53	12·05	3·07	
	3	11·81	4·17			
5th December 1953	1	15·68	3·18			
	2	16·65	3·25	15·62	3·50	
	3	14·54	4·06			
8th January 1954 ..	1	20·44	4·10			
	2	20·40	4·23	18·81	4·11	
	3	15·60	3·99			
4th February 1954 ..	1	27·32	6·03			Fallen leaves
	2	23·47	5·16	21·60	4·86	
	3	14·00	3·40			

TABLE IV

Phenological Observations at Sagar

Tree No.	Leaf appearance*	Flowering	Fruiting	Leaf-fall
1	3rd to 5th July 1953	24th to 26th July 1953	4th to 7th September 1953	Mid. Jan. 1954 to 1st week of April 1954
2	do	do	do	do
3	do	20th to 22nd July	28th August to 3rd September	Mid. December to 1st week of March

* This year (1954) the leaf buds appeared almost a month earlier, about the 1st week of June.

INTERPRETATION AND DISCUSSION OF THE RESULTS

From the available data provided by the locality study it is evident that direct correlation between soil pH and exchangeable soil calcium on the one hand and the calcium content of the leaves on the other cannot so easily be affected. The reasons are sufficiently apparent. The variations in the sampling time and phenological periods themselves afford explanation for some of the variations obtained. Samples from Nimar Division collected after flowering showed a greater calcium content. Besides, the attack of defoliator insect had been particularly heavy during the last year, throughout the State. Variation in the intensities of insect attack has produced some variation in the amounts of foliar calcium. Heavily infected samples from Allapalli (14 to 15) bring out this point and help to show that the general effect of defoliation is a fall of ash percentage with a corresponding decrease in the calcium content.

Chandler's (1941) critical pH of 4·5 for maple at which the availability of calcium is impaired does not provide a basis for correlation between factors in case of teak. This is due to the absence of such acid conditions in teak soils. Similarly, it appears from the data on exchangeable calcium, that calcium content of the leaves is not affected by variations within the ranges of calcium usually encountered in teak soils, nevertheless, as Chandler (1941) pointed out a more direct correlation might be found in the tree litters. Trees growing on calcareous soils may have a higher accumulation of this element in the litters.

While it is true in a general way that low pH affects calcium availability and that soil calcium is the source for the tree roots to draw upon, yet there are other factors like temperature, moisture, etc., that are involved in the absorption of the ions and no study can be complete without an insight into these factors—"nutrient uptake and nutrient requirement are not necessarily the same and that both vary with species and soil conditions" (Lutz and Chandler, 1946).

The data on calcium uptake as affected by age does not show any prominent period of 'maximum requirement' for calcium. There are,

however, some faint indications to show that at polewood (20 to 25 years of age) there is a greater amount of calcium uptake, but the number of samples is so small that it would be improper to indicate broad generalities. Further work is, therefore, needed to warrant a final decision.

The data on seasonal variation of foliar calcium shows that there is a gradual tendency for the percentage of calcium content to increase with the advance of growing season. A fairly smooth curve pattern is obtained (Fig. 1). This is in line with the observations of McHargue and Roy (1932) and Chandler (1939).

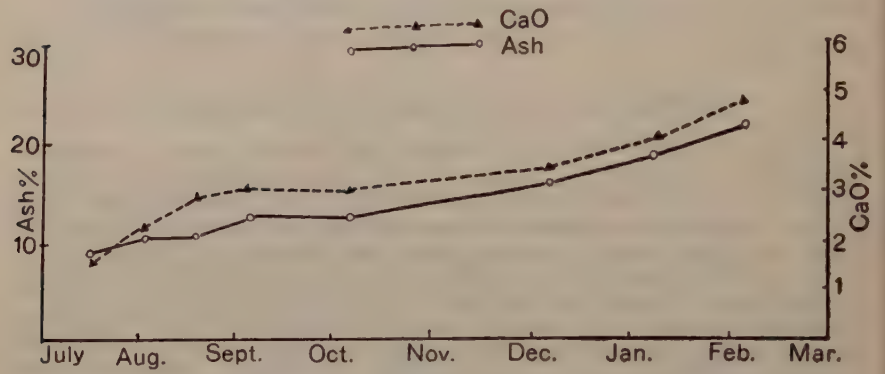

FIG. 1. Seasonal variation in foliar ash and calcium studied at Sagar.

It is interesting to note that the seasonal variation of foliar ash and calcium studied by Puri and Gupta (1954) shows dissimilar trends (Fig. 2).

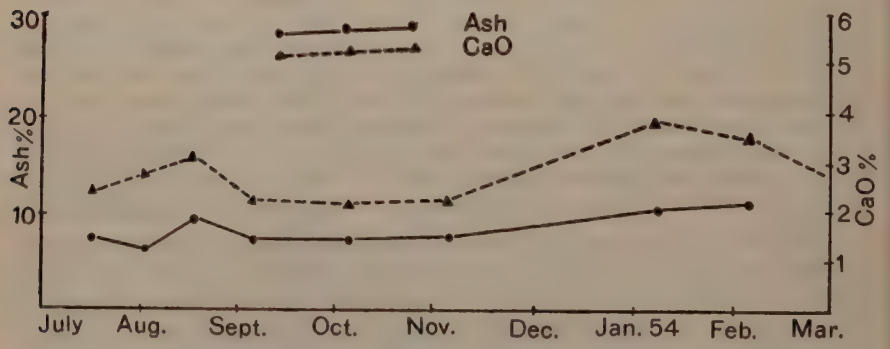

FIG. 2. Seasonal variation in foliar ash and calcium based upon the results of Puri and Gupta (1954), worked out for exotic teak at Dehra Dun.

According to Maximov (1938) ash accumulation in the plant depends generally upon the higher amounts of salts in the soil and dry climate.

Puri (1954) in a study of the soil climate at Dehra Dun, U.P., has shown that seasonal variations in foliar calcium is correlated with the variation in the exchangeable calcium of the soil. Under monsoonic climate the amount of calcium found in the soil is lowest during the rains, when leaching intensity is at the highest. This coincides with the period when calcium of the leaves is at the lowest. Subsequent rise in the soil calcium was followed by corresponding rise in the foliar calcium. It appears that explanation for seasonal variation cannot follow the lines indicated by him. This is due to the fact that such variations have been recorded by workers from the temperate regions as well, where the soil climate is more uniform in respect to leaching of bases and changes in soil climate are less drastic than those we have in the tropics.

It would appear at the moment, that it is best to consider the increase in foliar calcium to result from the accumulation of the element in the leaf where it is tied up in such insoluble form as calcium oxalate or pectate, rendering the element immobile with little chances of calcium being back transported. Towards maturity of the leaves, however, the capacity to accumulate minerals is lessened; this might explain the slight drop of calcium percentage towards leaf-fall.

There is some evidence to show that calcium content of the leaves increases with the lengthening of the growth period. Delayed leaf-fall in the first tree shows a marked increase in the amount; there are possibilities of 'luxury consumption' being involved in this case for the occurrence of a rich deposit of lime in the sub-soil provide an inexhaustible source for the tree to draw upon.

On basis of the present investigation, seasonal variation in the amounts of foliar calcium is indicated. The results of Puri and Gupta (1954) and those of the present investigation show dissimilar trends in the seasonal variation. Such variations in the results may be due to different climatic conditions under which teak grows. The absorption of ions are known to be affected by such factors as light, temperature and moisture (Hoagland and Arnon, 1941; Hoagland, 1923 and Krammer, 1949). Besides there are good indications to believe that we are not dealing with a uniform teak population, in fact the divergent physiological behaviour points to that. The present study is, therefore, indicative of the fact that either the nutritional balance of the forest trees is disturbed when introduced in areas outside the natural limits of the species or that we have distinct physiological races. Much work would, therefore, be needed to bring forth the variations obtainable in nature and ascribe suitable reasons for them.

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EMBRYOLOGICAL STUDIES IN BORAGINACEÆ

I.—Coldenia procumbens Linn.

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(Received for publication on March 30, 1955)

Introduction

Although the family Boraginaceæ received considerable attention from embryologists for a long time, our information relating to the sub-families Ehretioideæ and Cordioideæ is rather scanty. The statements and figures by Svensson (1925) indicate that in the ovules of *Heliotropium*, *Ehretia* and *Cordia* there is a tissue between the epidermis and the megaspore mother cell or between the former and the megaspore tetrad suggesting that either the nucellar epidermis undergoes a periclinal division or that the primary archesporial cell cuts off a perietal cell which divides anticlinally and forms a layer of cells. Presence of such a layer of cells arising in one or the other of the ways mentioned above is met with only in few sympetalæ such as *Convolvulus* sp. (Peters, 1908), *Convolvulus arvensis* (Mathur, 1934), *Ipomea liearii* (Raghava Rao, 1940), *Heliotropium* (Svensson, 1925) and *Cobæa* (Dahlgren, 1927). So far as our present knowledge goes, however, both the above described situations are not known to occur within the same family.

A brief summary of the embryological work already done in the family up to 1925 is contained in *Vergleichende Embryologie der Angiospermen* by Schnarf (1931). After the publication of this book the most important works on the family concern the development of the embryo in *Myosotis hispida*, *Lycopsis arvensis*, *Echium vulgare*, *Symphytum officinale*, *Heliotropium peruvianum* by Souèges (1921 *a* and *b*; 1923; 1938 *a* and *b*; 1941, 1943) and *Eritrichium* by Crété (1953). The embryological features of the family are given below:—

The division of the pollen mother cells is simultaneous and the tapetum is of the secretory type. In all the sub-families the ovules are tenuinucellate and unitegmic. In Heliotropioideæ and Ehretioideæ there seems to be a one-layered tissue corresponding to parietal tissue. Integumentary vascular bundles are recorded in some Boraginaceæ like *Borago* and *Nonnea*. The embryo-sac development is of the Polygonum type except in *Lycopsis arvensis* and *Anchusa officinalis* in which it is reported to be of Scilla type (= Allium type) by Svensson (1925). The antipodals are ephemeral. In *Heliotropium europæum* (Svensson, 1925) six antipodals are found. In some Anchuseæ a lateral diverticulum is developed by the embryo-sac (Svensson, 1925). Fertilisation is porogamous and an obturator has been reported in Heliotropioideæ.

The mode of endosperm formation shows a great variation in the family. In Cordioideæ, Ehretioideæ and Heliotropioideæ it is cellular. Within the tribe Lithospermæ, it is cellular in *Myosotis* but nuclear in *Onosma* (Svensson, 1925). Helobial type of endosperm formation takes place in Echieæ while in Eritrichieæ and Cynoglosseæ there occurs an intermediate type between the cellular and nuclear types. Micropylar and chalazal endosperm haustoria are developed in some members of the family (Svensson, 1925).

The embryo development is diverse in the different members of the family and as many as five different variations distributed in two different types of embryo development are known to occur within the family. For instance, Polemonium variation of Chenopodiad type in *Echium vulgare* (Souèges, 1938 *b*; Johansen, 1950), Lamium variation of Asterad type in *Lycopsis arvensis* (Souèges, 1943) and Myosotis variation of Chenopodiad type in *Eritrichium* (Crété, 1953) have been described.

As already mentioned, in spite of extensive embryological work in the family, the sub-families Ehretioideæ and Cordioideæ remain rather poorly known embryologically and Svensson (1925) himself states that his studies on *Ehretia* and *Cordia* are incomplete being based only on insufficient and ill-fixed materials.

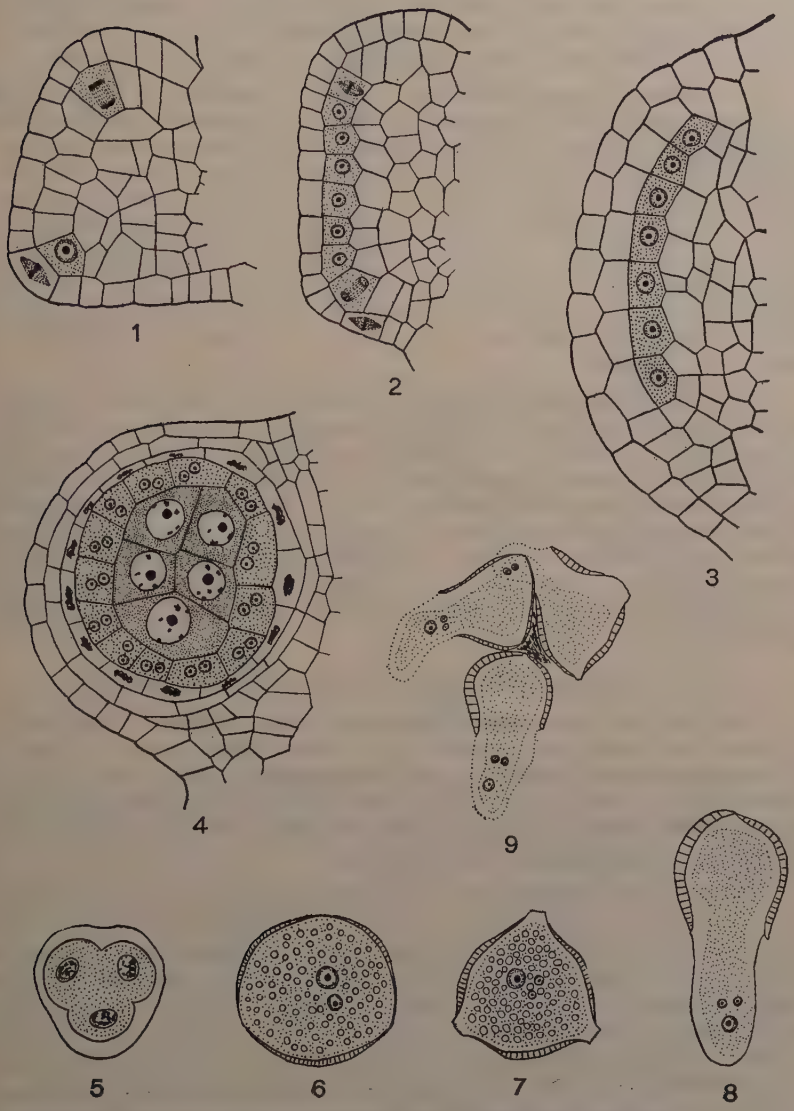
Therefore it appeared to us that further detailed study of the family is worthwhile. The present paper deals with *Coldenia procumbens*, a member of Ehretioideæ which occurs in abundance on the margins of water tanks and rice fields throughout India.

Material and Methods

The material used in this investigation was fixed in F.A.A. and Aceto-alcohol. Customary methods of dehydration, clearing and infiltration were followed. Sections were cut at a thickness of 6 to 12 μ and stained with Harris' hæmotoxylin or Delafield's hæmotoxylin of which the former proved to be better.

Microsporogenesis and Male Gemetophyte

In *Coldenia procumbens* there are four or five epipetalous stamens. In very early stages of development the anther consists of a homogeneous mass of meristematic cells. Just as the four lobes become recognisable in the anther the primary archesporium, which consists of a hypodermal row of seven or eight conspicuous cells, becomes differentiated (Figs. 1 and 2). Very soon each of the archesporial cells undergoes a periclinal division resulting in the formation of a layer of primary parietal cells to the outer side and a layer of sporogenous cells to the inner side (Fig. 3). The primary parietal layer once again divides periclinally forming two wall layers the inner of which forms the anther tapetum. The outer layer, however, undergoes one more periclinal division and gives rise to two cell layers between the epidermis and the tapetum. The sub-epidermal wall layer forms the fibrous endothecium in the mature anther and the middle layer



FIGS. 1–9. Various stages showing the structure and development of anther and pollen. Fig. 1. T.S. $\frac{1}{2}$ an anther showing primary archesporium. Fig. 2. L.S. anther lobe showing the same. Fig. 3. L.S. anther lobe showing primary parietal and sporogenous layers. Fig. 4. T.S. anther lobe, older stage. Fig. 5. 4-nucleate P.M.C. showing cytokinesis by furrowing. Figs. 6 & 7. 2-celled and 3-celled pollen grains with starch grains. Fig. 8. Pollen grain which has germinated *in situ*. Fig. 9. A pollen tetrad from an abnormal anther in which the pollen grains have already germinated. Only three pollen grains are seen in the figure and in the pollen tube of one of them the vegetative nucleus is not seen in the section from which it is drawn. Figs. 1 & 3, ×727; Fig. 2, ×557; Figs. 4–9, ×1090.

degenerates and becomes crushed. The tapetal cells become binucleate usually by about the time when the pollen mother cell nuclei are at the diakinesis stage during the first meiotic division (Fig. 4). They become absorbed by about the time two-celled pollen grains are formed.

The primary sporogenous layer divides a number of times in all directions forming the sporogenous tissue. The pollen mother cells undergo the usual two meiotic divisions in a simultaneous manner. Cytokinesis takes place by furrowing (Fig. 5). Both the tetrahedral and bilateral pollen tetrads are found, the former type being predominant. A small generative and a larger vegetative cell separated by a thin curved membrane are formed after the first division in the pollen grain. Pollen grains are two-celled in their shedding stage and are loaded with starch grains (Figs. 6 and 7). There are three germ pores in as many germinal furrows in the exine which shows rod-like thickenings in its structure.

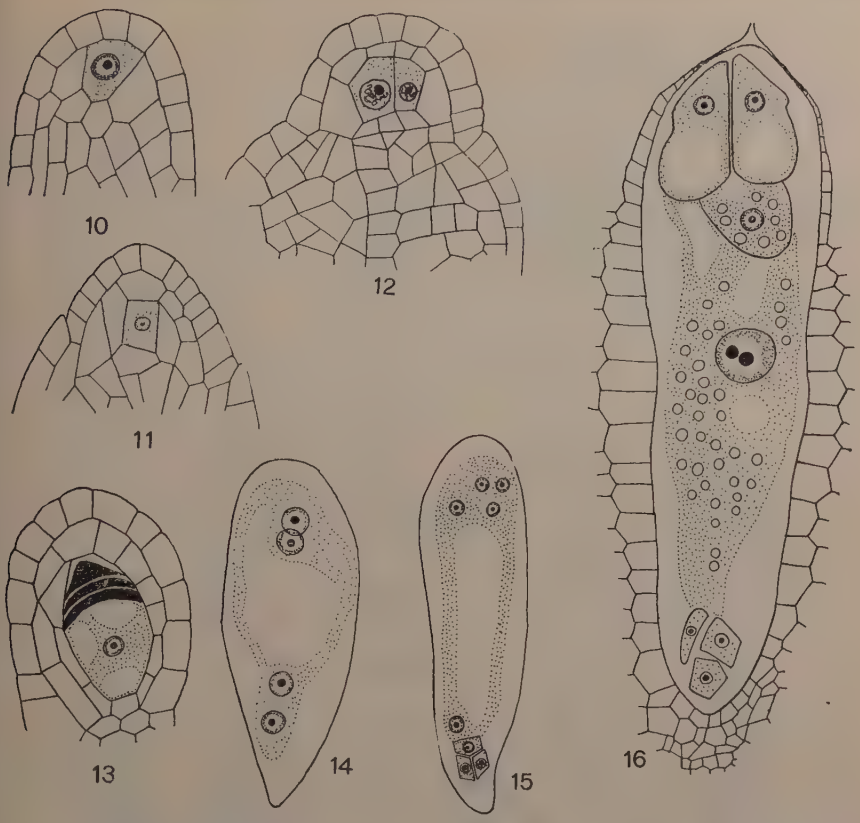
In a few preparations a peculiar situation was met with. In some flowers the corolla did not drop off as usual but persisted in a shrivelled up condition enclosing the anther. In these the pollen grains were locked up in the anther lobes and the generative nucleus had already divided forming two male gametes (Figs. 7 and 8). Figure 9 shows a case in which the pollen grains belonging to the same tetrad did not become free from one another but germinated while retaining their original positions in the tetrad. In these also the vegetative nuclei and the male gametes have already moved into the corresponding pollen tube.

Megasporogenesis and Female Gametophyte

The ovary is syncarpous, bicarpellary and imperfectly four-celled. The two styles which are distinct at the base cohere above. There is one hemianatropous, unitegmic and tenuinucellate ovule in each loculus. The integument is about ten cell layers thick at the time the eight-nucleate embryo-sac is formed. The innermost layer forms the integumentary tapetum (Figs. 16, 17 to 24).

An obturator consisting of a massive glandular tissue arises from the region of the attachment of the funicle to the placenta and extends to the micropyle taking its course along the upper part of the funicle (Fig. 17). The funicle and this structure give an appearance of being fused with each other but on close examination their epidermal layers can be made out to be separate. Thus the funicle and the obturator are only closely appressed to each other. An obturator has previously been recorded in the family only in *Heliotropium* (Svensson, 1925).

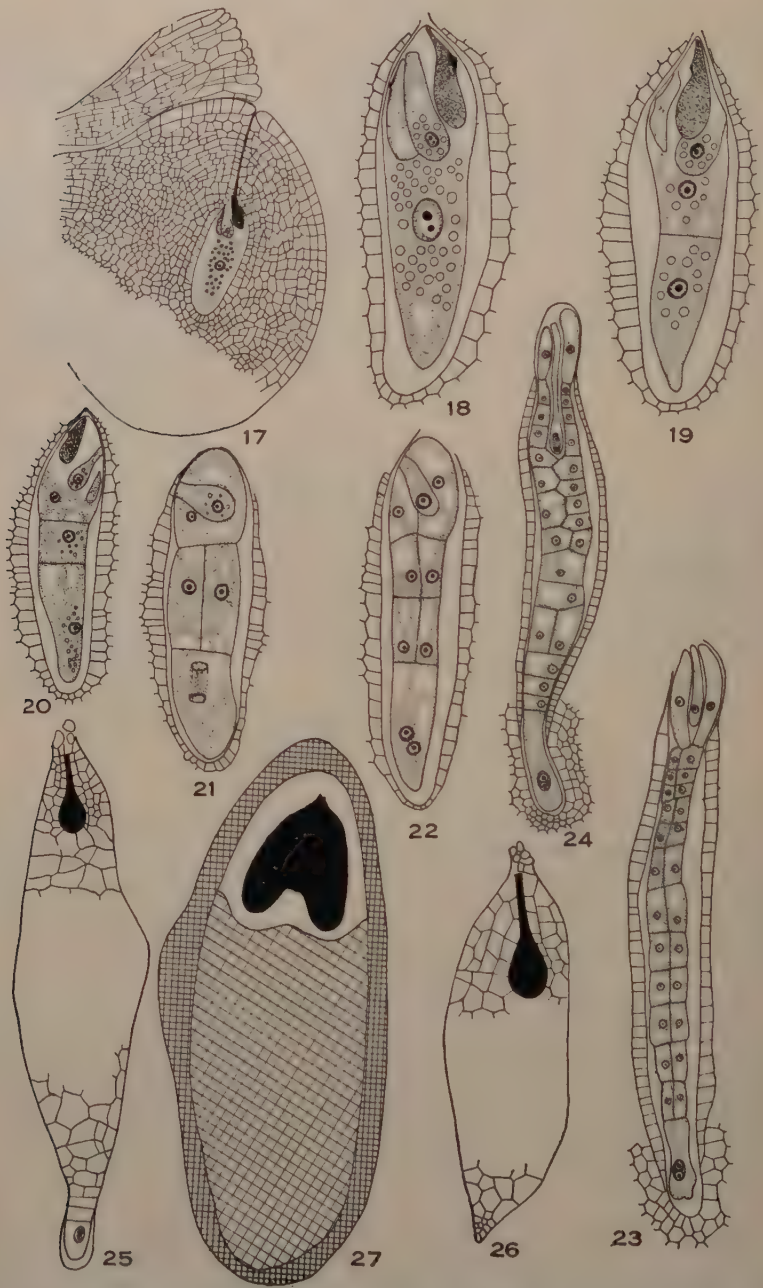
The primary archesporium consists of a single hypodermal cell which becomes distinguishable before the integumentary primordium makes its appearance (Fig. 10). It enlarges in size and undergoes a mitotic division giving rise to a primary parietal cell which a little later divides anticlinally (Figs. 11 and 12). The occurrence of parietal cell or cells is previously known only in a few sympetalæ as already mentioned. In Boraginaceæ, Svensson (1925) noted the occurrence of cells between the nucellar epidermis and the megaspore mother cell



FIGS. 10–16. Megasporogenesis and female gametophyte. Fig. 10. L.S. young ovule with 1-celled archesporium. Fig. 11. L.S. ovule showing primary parietal cell and M.M. cell. Fig. 12. L.S. ovule with 2 M.M. cells above each of which there is a parietal cell. Fig. 13. Linear tetrad of megaspores in which the three micropylar cells are in an advanced stage of degeneration and the chalazal is functional. Figs. 14–16. Various stages in the development of the embryo-sac. Figs. 10 & 15, ×1090; Figs. 11 & 12, 14 & 16, ×727; Fig. 13, ×937.

in *Ehretia macrophylla* and *Heliotropium europæum* but he could not establish the origin of these cells in the former species. Observations made by us on *Heliotropium curassavicum* show that the cells in question arise as a consequence of a periclinal division in the cells of the nucellar epidermis. Later, these cells become crushed completely along with the nucellar epidermal cells by the growing embryo-sac both in *Heliotropium curassavicum* and *Coldenia procumbens*. Figure 16 shows the same in the latter.

Usually only one megaspore mother cell is found in an ovule. Occasionally, however, cases of ovules with two megaspore mother cells have also been met with (Fig. 12). Although no case of *Coldenia procumbens* with two archesporial cells has been encountered during the present study, it may be surmised from this that occasionally the



FIGS. 17–27. Fig. 17. L.S. mature ovule with the obturator. Fig. 18. Embryo-sac showing syngamy and triple fusion. The attacked and unattacked

synergids can be seen on either side of the egg. Figs. 19–27. Various stages in the development of the endosperm (see text for detailed explanation). In Figs. 25 and 26 endosperm cells in the middle part are not represented. Fig. 27. Diagram of embryo-sac showing embryo and the peripheral and central regions of the endosperm. Fig. 17, ×193; Figs. 18 & 19, ×485; Figs. 20–22, ×340; Fig. 23, ×242; Fig. 24, ×150; Figs. 25–27, ×86.

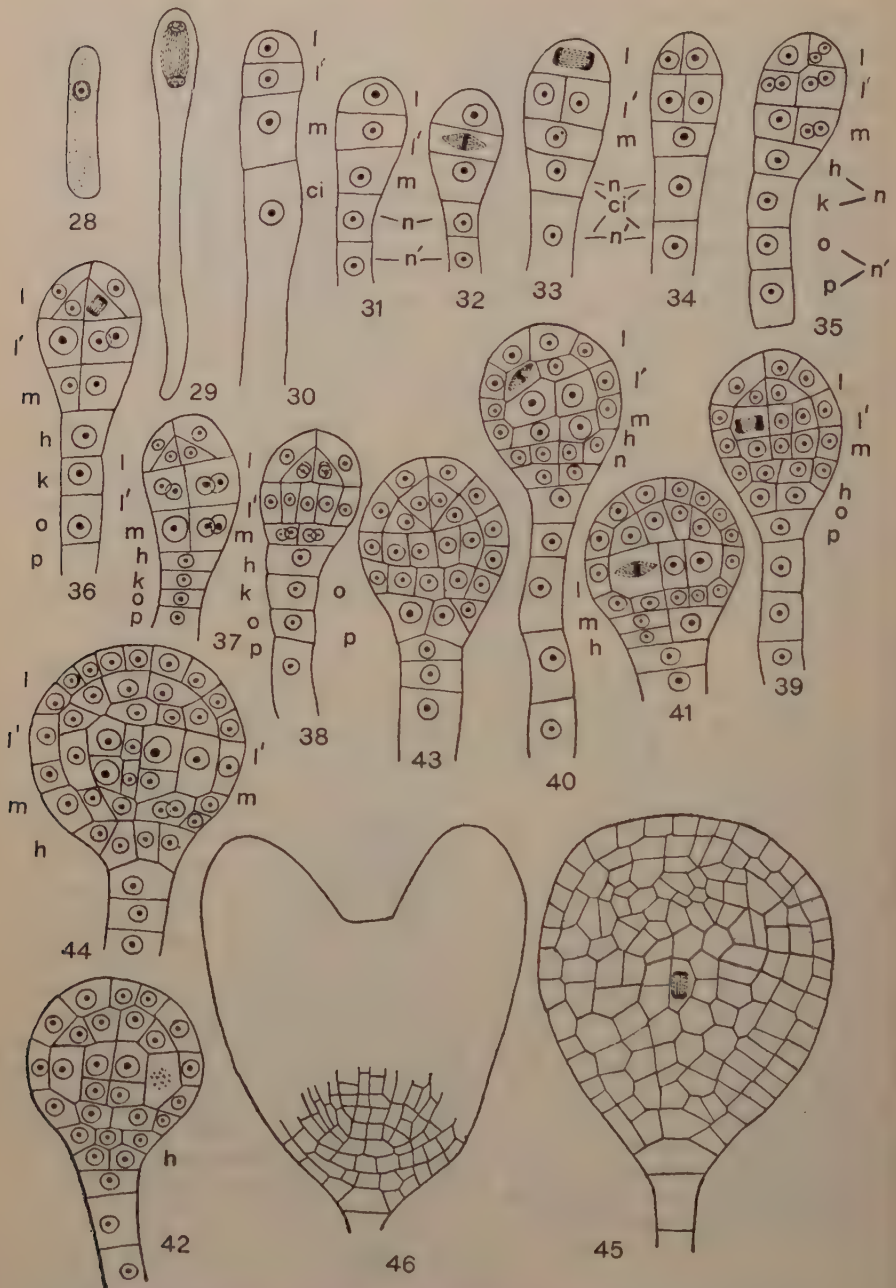
primary archesporium may consist of more than one cell. A linear tetrad of megaspores is formed consequent upon the usual two meiotic divisions. The chalazal megaspore enlarges and develops into the uninucleate embryo-sac, while the three upper megaspores of the tetrad degenerate (Fig. 13). An eight-nucleate embryo-sac is formed after three successive free nuclear divisions take place in one-nucleate embryo-sac (Figs. 13 to 16). There are three antipodals and these are organised as cells earlier than the cells of the egg apparatus. These disappear before fertilisation. Synergids are hooked. The synergids and egg show usual features in their form and structure. The egg contains many starch grains (Fig. 16). Occurrence of starch grains in the egg cells is reported previously in such plants like *Astilbe grandis*, *Aspidistra elatior*, *Acacia baileyana*, *Medicago sativa*, *Korthalsella opuntia*, *Zea mays*, *Euchlæna mexicana*, *Portulaca oleracea* and *Phryma leptostachya* (Maheshwari, 1950). Starch grains are also present in the cytoplasm of the embryo-sac of *Coldenia procumbens* (Figs. 16 to 18). The polar nuclei fuse about the middle of the embryo-sac before fertilisation.

Fertilisation

Fertilisation is porogamous. While the pollen grains usually germinate on the stigma, a few cases have been met with where they germinated in the undehisced anthers and these have already been described earlier in this paper. The pollen tubes course their way through the stigma and the style in an intercellular manner. From the region of the placenta they are guided in their course by the obturator. The pollen tube enters the narrow and long micropyle after leaving the obturator and finally reaches the micropylar end of the embryo-sac which it penetrates at the place where one of the synergids is situated (Fig. 17). The pollen tube attacks one of the synergids and discharges its contents into it. Both synergids disappear before the fertilised egg undergoes the first division which is delayed till the formation of the four cells constituting the micropylar haustorium and formation of cellular tissue in the middle chamber of endosperm and the fusion of the two-nuclei of the two-nucleate chalazal chamber of the endosperm (Fig. 24). Syngamy and triple fusion take place at about the same time (Fig. 18). The pollen tube collapses in the micropyle and disappears after fertilisation and no remnants of it can be seen in later stages. The integument margins bordering on the micropyle also become closer and the micropyle can only be made out as an extremely narrow canal.

Endosperm

The endosperm is of the cellular type. The first division of the primary endosperm nucleus is completed very much before that of



FIGS. 28–46. Various stages in the development of the embryo (see text for detailed explanation). Figs. 28–44, ×562; Fig. 45, ×362; Fig. 46, ×575.

the fertilised egg. It is accompanied by the formation of a transverse wall partitioning the embryo-sac into an upper and a lower chamber (Fig. 19). The latter elongates more rapidly and divides once transversely forming two superposed chambers (Fig. 20). Thus the embryo-sac is divided into three chambers, namely the micropylar, the middle and the chalazal chambers. The micropylar chamber contains the zygote and the remnants of the degenerating synergids (Fig. 20). Later the micropylar chamber undergoes two vertical divisions at right angles to one another forming four circumaxially arranged cells which form the micropylar haustorium.

The divisions in the middle chamber take place earlier than those in the micropylar chamber. It rapidly elongates and divides by a longitudinal wall (Fig. 21). This is followed by longitudinal and transverse divisions in which the cell walls are laid in a regular fashion after each division (Figs. 21 to 23). The derivative cells from this chamber form bulk of the endosperm tissue (Fig. 24). In advanced ovules the cellular endosperm tissue derived from the middle chamber can be recognised into two zones, a peripheral zone of compactly arranged cells and a central region of loosely packed large endosperm cells with intercellular spaces forming a spongy tissue (Fig. 27). In very advanced ovules this tissue becomes completely abosorbed by the embryo.

At about the same time when the first cellular division takes place in the middle chamber, a nuclear division takes place in the chalazal chamber (Figs. 21 and 22). The two nuclei so formed fuse later on (Figs. 23, 24 and 25). The fused nucleus is about twice as large as the nuclei of the cells derived from the micropylar and middle chambers of the endosperm. As the two nuclei of the chalazal chamber are triploid, the fusion nucleus of the chalazal chamber would be hexaploid while the nuclei contained in the cells derived from the micropylar and middle chambers remain triploid. The lower end of the chalazal chamber becomes slightly swollen and feebly lobed (Fig. 23). The chalazal chamber elongates further and becomes filled with dense cytoplasm. It serves as a chalazal endosperm haustorium. In still older ovules in which the embryo attains the globular form a cell division sets off the lower part from the upper. In the latter a few cell divisions take place later forming a small-celled tissue which abuts towards the lower side of the cellular tissue derived from the middle chamber. In still later stages of seed development the chalazal chamber becomes crushed by the tissue above it and as mentioned already in mature seeds all the endosperm is completely consumed by the embryo.

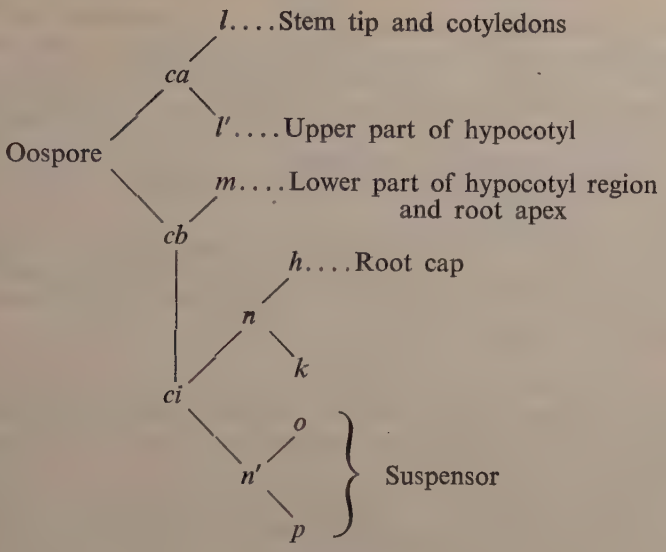
Embryo

The first division of the fertilised egg takes place after the micropylar and chalazal haustoria are fully differentiated and the cellular endosperm tissue is well developed in the middle chamber. At first the fertilised egg is clasped around by the four cells of the micropylar haustorium. The fertilised egg elongates considerably before the first division takes place in it. The first division is transverse (Fig. 29) and results in the formation of a two-celled proembryo comprising a terminal cell *ca* and a basal cell *cb* both of which divide once transversely

and form a four-celled proembryo in which all the cells are arranged in a linear row. They may be designated as *l*, *l'*, *m* and *ci* (Fig. 30). Next *ci* divides transversely and gives rise to two superposed cells which may be designated as *n* and *n'* and thus a proembryo of five superposed cells is produced (Fig. 31). Of these five cells *l'*, *l* and *m* divide longitudinally twice in the order mentioned and the walls laid in the two divisions in each of them are at right angles to one another forming quadrants in the tiers *l*, *l'* and *m* respectively (Figs. 32–35). By about this time the cells *n* and *n'* undergo a transverse division each and produce four cells which may be designated as *h*, *k*, *o* and *p* of which *h* and *k* are the derivatives of *n* and *o* and *p* are the derivatives of *n'* (Fig. 35). Then periclinal divisions take place in the four circumaxially arranged cells of the tier *l* as a result of which dermatogen becomes demarcated in this tier (Figs. 37 and 38). The same happens in the tier *l'* and *m* also. By about the time the dermatogen is differentiated in the tier *m*, the cells of the tier *l'* become divided in a transverse manner (Fig. 44). The cell *h* forms the hypophysis. It undergoes two vertical divisions the walls formed in which are at right angles to each other thereby producing four circumaxially arranged cells in the tier *h*. Each of the cells of this tier becomes divided more or less horizontally and their derivatives form the root tip and the root cap (Figs. 41 and 42). The cells *k* and *o* divide further in a transverse manner resulting in an increase in the number of cells which constitute the suspensor. The cells in the various tiers *l*, *l'*, *m* and *h*, excepting those of the dermatogen, divide both longitudinally and transversely as a result of which the embryo becomes globular (Fig. 45). Later cotyledon protrusions are formed in the tier *l* (Fig. 46).

From the foregoing account it can be seen that at the second cell generation the proembryo consists of four cells in four tiers and at the third cell generation of eight cells disposed in five tiers. The derivatives of the terminal tier *l'* give rise to the upper half of the hypocotyledonary region, those of the tier *m* give rise to the lower portion of the hypocotyledonary region and the root apex also, while the suspensor is formed from the derivatives of *k*, *o* and *p*. Thus the derivatives of the terminal and basal cells of the two-celled proembryo contribute to the formation of the embryo proper. These features are characteristic of the Chenopodiad type of embryo development.

The following scheme shows the relation of the different organs of the mature embryo to the specific cells of the proembryo.



Discussion

In *Coldenia procumbens* the development of the anther and pollen show no unusual features. The pollen grains are usually shed in the two-celled condition and contain abundant starch grains. Strasburger (1884), however, noted the occurrence of three-celled pollen grains in *Pulmonaria saccharata.* Unshed pollen grains in a few anthers of *Coldenia procumbens* were also seen to become three-celled and even germinate and form pollen tubes in the pollen sacs.

The ovule is hemi-anatropous, unitegmic and tenuinucellate as in other Boraginaceæ and Sympetalæ in general. A feature of exceptional interest is the occurrence of parietal cells in *Coldenia procumbens*, a feature known only in a few other Sympetalæ. Occurrence of a tissue between the nucellar epidermis and the megaspore mother cell in *Ehretia* noted by Svensson (1925) is also probably due to the formation of a parietal cell in the ovule. This feature probably occurs in Ehretioideæ in general and is worth investigating further.

The embryo-sac development is of the Polygonum type. Obturator formation which takes place in *Coldenia procumbens* is previously known only in one another genus within the Boraginaceæ, namely *Heliotropium.* Thus *Coldenia* and *Heliotropium* resemble each other in the occurrence of an obturator and the presence of a tissue between the nucellar epidermis and the megaspore mother cell though it arises in different ways in the two genera. Long ago, Van Tieghem (1906) favoured the view that the Heliotropoideæ may be treated as a separate sub-family but the occurrence of the above referred features in *Coldenia* and *Ehretia* does not make *Heliotropium* so different as to justify placing it in a distinct sub-family.

There is no previous information on the endosperm development in Ehretioideæ to which belongs *Coldenia procumbens*. The endosperm in this plant is different from that of the other investigated members of the family in the differentiation of micropylar and chalazal haustoria and the cellular endosperm tissue between them while in other Boraginaceæ only a micropylar haustorium is developed. Thus *Coldenia procumbens* adds to the range of variation in endosperm found in the family.

The embryo development also shows a great deal of variation within the family. In *Coldenia procumbens* it is of the Chenopodiad type and in this feature it resembles *Myosotis hispida* and *Echium vulgare* (Souèges, 1923 and 1938).

Summary

The development and structure of the anther and pollen, ovule and embryo-sac, endosperm and embryo in *Coldenia procumbens* have been described.

The primary archesporium in the anther consists of a hypodermal row of seven or eight cells in each lobe. The fully developed anther shows the epidermis, fibrous endothecium, a middle layer and a secretory type of anther tapetum of parietal origin surrounding the sporogenous tissue. The pollen mother cells divide in a simultaneous manner and form both tetrahedral and bilateral pollen tetrads. Cytokinesis takes place by furrowing. The pollen grains are usually two-celled at the shedding stage but in a few abnormal cases where they are retained unshed within the anther lobes they become three-celled and even germinate *in situ*. The exine shows three germ pores situated in as many germinal furrows.

The ovule is tenuinucellate, unitegmic and hemi-anatropous. A feature of exceptional interest is the presence of parietal cells in the ovules of *Coldenia procumbens*. An obturator is developed from the placental tissue and the innermost layer of the single massive integument forms an integumentary tapetum. The primary archesporium in the ovule is single celled. A linear tetrad of megaspores is formed and an eight-nucleate embryo-sac is developed according to the Polygonum type. The egg and the cytoplasm of the embryo-sac contain starch grains and the synergids are hooked in the upper part. Antipodals disappear before fertilisation. The nucellar epidermis is destroyed by the embryo-sac during its growth.

Fertilisation is porogamous. The endosperm is of the cellular type. It consists of three regions, a micropylar haustorium of four cells, middle cellular endosperm tissue and binucleate chalazal chamber functioning as chalazal haustorium. The latter ultimately becomes cellular and becomes absorbed along with the rest of the endosperm.

The embryo development has been studied in detail and it conforms to the Chenopodiad type.

Embryological features in which *Coldenia procumbens* differs from the other Boraginaceæ and Sympetalæ have been outlined and it is

pointed out that *Coldenia procumbens* resembles *Heliotropium* in certain features.

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A CONTRIBUTION TO THE MORPHOLOGY OF *CENTELLA ASIATICA* (LINN.) URBAN, AND SOME OTHER RELATED SPECIES *

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(With 52 Text-Figures)

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Introduction

Although Urban removed *Hydrocotyle asiatica* Linn. to *Centella asiatica* in 1879, one still finds the invalid name appearing in taxonomic literature (see Rendle, 1925). Both *Centella* and *Hydrocotyle* are interesting genera in so far as they lack some of the common characters of the Umbelliferæ, *e.g.*, the compound leaves with sheathing leaf bases, hollow internodes, compound umbel inflorescence and a carpophore in mature fruit. Our knowledge about the floral morphology of these genera is rather fragmentary. The only recent work in which some species of *Hydrocotyle* are included is that of Jackson (1933). The floral anatomy of *Centella asiatica*, however, has not been studied so far. As it is likely to be of more than passing interest, the present study was undertaken about 2 years ago. For the sake of comparison some species of *Hydrocotyle* also have been studied and described.

Material and Methods

Flowers, buds and fruits of *Centella asiatica* were collected locally while those of *Hydrocotyle conferta* Wight were obtained from the herbarium sheets of the Botany Department, Meerut College, Meerut, collected from Kodaikanal in 1950. Flowers and fruits of *Hydrocotyle rotundifolia* Roxb. were kindly spared for me by Dr. V. Puri from the sheets of his recent Nepal collection.

Herbarium material was first treated with 5% sodium hydroxide solution at 60° C. for about 24 hours, then washed and fixed in F.A.A. Fruits, being hard, were treated with 50% hydrofluoric acid for 15 days. After a thorough washing they were dehydrated with ethyl alcohol and embedded in paraffin. Serial microtome sections, both longitudinal and transverse, were cut from 10–14 microns thick. While slides of alcohol-preserved material were stained with crystal violet and erythrosin those of the herbarium material gave better results with safranin and fast green.

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* Research Paper No. 6 from the School of Plant Morphology, Meerut College, Meerut.

Observations

1. *External morphology of the flower*

Centella asiatica (Linn.) Urban.—It is a small, herbaceous perennial weed spreading by creeping rhizome and found in moist muddy soil or even under water. The plant is much used as an important tonic, especially for children and has some reputation for treatment of skin complaints.

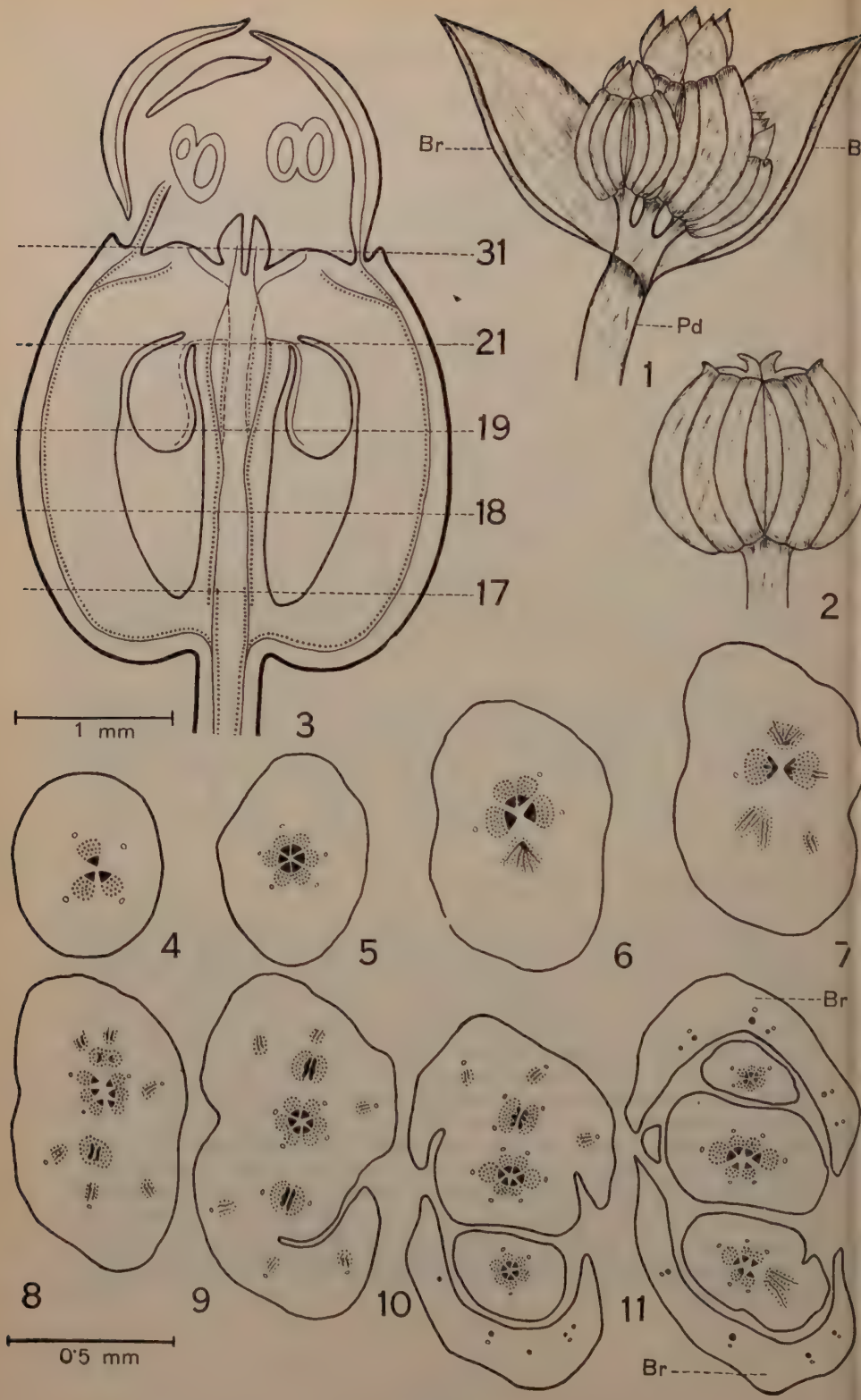
Flowers are borne in axillary cymes on peduncles half an inch long (Fig. 1). Each cyme is enclosed within a pair of big involucral bracts and consists of three laterally compressed flowers, the central one being the oldest. In very few cases four or even five flowers were seen in an inflorescence having an involucre of more than two bracts. Two instances of compound inflorescence were also seen. Here the peduncle instead of bearing flowers bore four or five peduncles, each of which produced three flowers (Figs. 34–38).

Flowers are small, actinomorphic and epigynous. The gynæceum is bicarpellary and somewhat saccate at the base. It is crowned by a glandular disc, the stylopodium, that bears two divergent styles. In place of the sepals there is an annular rim which is very rudimentary. There are five petals which alternate with five stamens that are incurved in bud condition.

In *Hydrocotyle rotundifolia* Roxb. the inflorescence is shortly peduncled and contains 10–15 flowers which are sub-sessile and arise in whorls at different levels. Though Hooker (1879) describes the bracts as obscure, I found the outer bracts as big as the flowers. Those for the younger flowers are, however, small. There is no annular rim corresponding to that in *Centella asiatica*. *Hydrocotyle conferta* Wight, resembles this species in all essential respects.

2. *Vascular anatomy of the flower*

Centella asiatica (Linn.) Urban.—The stele in the lower region of the peduncle consists of three endarch more or less equal bundles (Fig. 4). A little higher up they break up into six bundles which are equidistant from one another (Fig. 5). Then the peduncle flattens and the bundles arrange themselves in three pairs, the central one being the largest (Fig. 6). As these pairs separate apart, the bundles of the outer ones fuse together into two vascular masses which supply three traces each to the bracts on either side (Figs. 7–9). The supply of one of the two bracts is somewhat different. Whereas two traces arise from the pedicel supply of the corresponding outer flower, the third trace seems to be given off from one of the two bundles meant for the median pedicel. The three bundles in each bract divide and redivide to form 8–10 bundles in the body of the bract (Figs. 10, 11). All bract bundles end freely and are accompanied on the outside by an oil duct. These ducts also accompany bundles in the pedicel, ovary 'wall', petals and stamens.



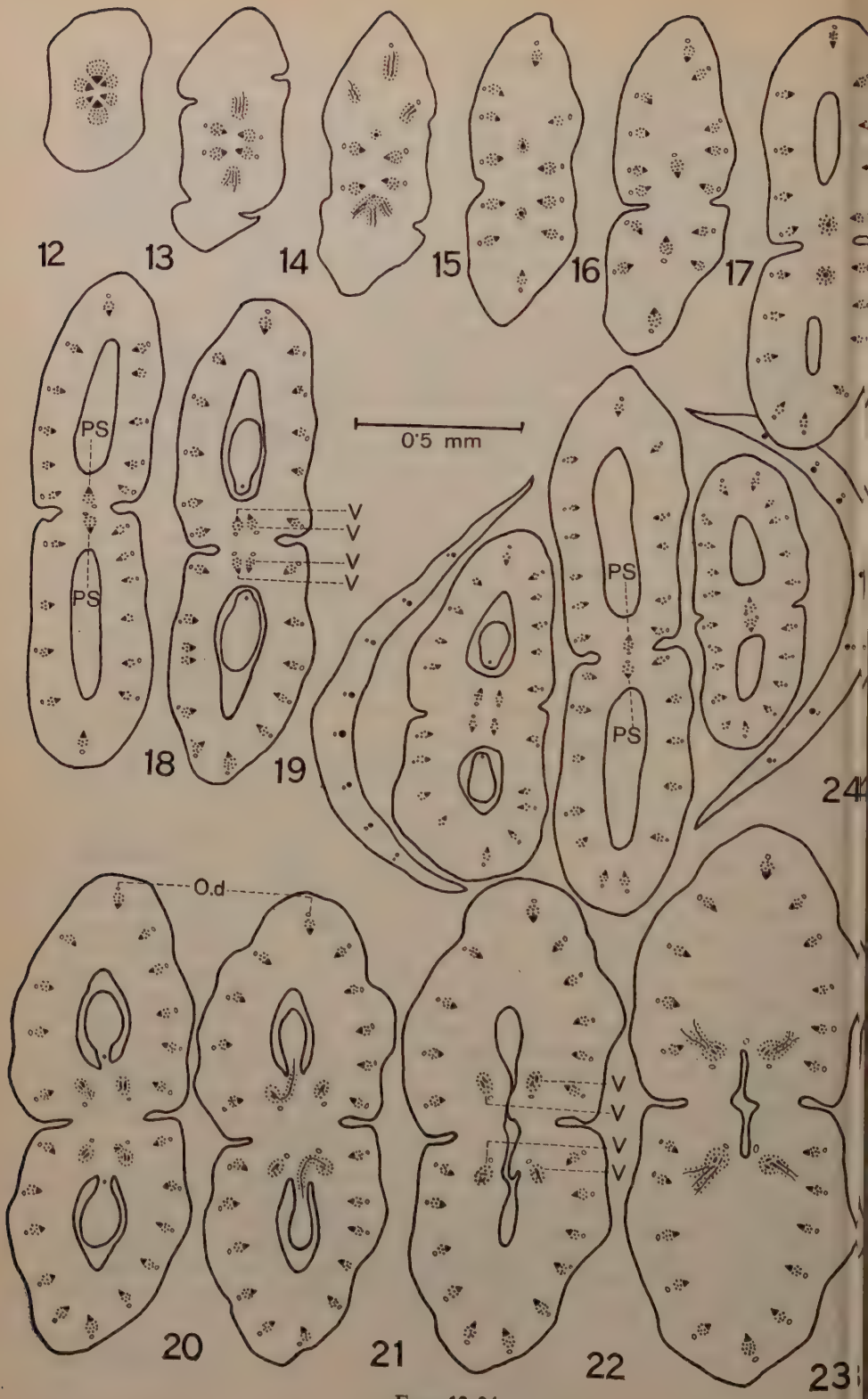
FIGS. 1–11

FIGS. 1–11. *Centella asiatica* (Linn.) Urban.—Fig. 1. An open inflorescence. Fig. 2. A mature fruit. Fig. 3. Semi-diagrammatic longitudinal section of the flower showing vascular supply to different floral organs. Figs. 4–11. Successive transverse sections through the inflorescence axis showing differentiation of bracts, pedicels and their vascular supply. Figs. 7 and 8 show the origin of three traces for each bract. The upper bract receives two traces from the adjoining pedicel supply and the third trace from one of the two bundles meant for the median pedicel. *Br*, = Bract. *Pd*, = Peduncle. Broken horizontal lines indicate the levels at which figures with the same numbers have been drawn.

The vascular mass left behind after the departure of the bract traces resolves itself into two patches, one on either side. Each patch splits up into three bundles (Figs. 8–10). The vascular supply of each pedicel is, therefore, exactly on the same plan as that of the parent peduncle. The bracts and their axillant pedicels now separate off from the central pedicel. The bundles of the median pair of the peduncle split into three small bundles each, which organise into a cylinder of six bundles for the central pedicel (Figs. 8–11). Every one of the three pedicels thus has a dissected siphonostele which behaves alike in all cases. Out of the six bundles of the cylinder the four that occur on the antero-posterior sides show no change except that they diverge out a little as the receptacle is approached (Figs. 12–15). These bundles correspond in position to the secondary marginal bundles of the carpels. The remaining two lateral bundles are the largest and give off three traces each (Figs. 14–16). The median of them corresponds in position to the dorsal bundle of the respective carpel while the laterals divide a number of times forming many bundles which traverse the primary and secondary ridges of the ovary 'wall' (Figs. 17–24).

After the passing out of these bundles there is left behind some amount of vascular tissue which organises itself into a single bundle on either side (Figs. 15, 16). This latter bundle corresponds in position to the placental strand of the corresponding carpel. It is significant to note that these bundles which are normally oriented to begin with, become inversely oriented in the region of the ovary. This change is effected either by the bundles becoming concentric and then exarch (Figs. 16–18) or by their splitting into two daughter bundles which after rotating through 180° fuse into inverted bundles. For a short distance about the middle of the ovary, the placental strands (PS) of the two sides come very near to each other. But a little higher up they again separate apart and then split into two each in the ovule bearing region (Fig. 19). The two daughter bundles of each strand separate apart a little and then the alternating ones give off one ovular trace each (Figs. 20, 21). For instance in Fig. 21 the upper ovule is receiving its supply from the left bundle of one pair and the lower one from the right of the other. This is an important structural feature which may indicate the trend of specialization in the gynæceum.

In the upper part of the ovary, after the disappearance of the ovules the two loculi become interconnected through an extremely narrow slit which persists only for a few sections (Figs. 22, 23). Such a merging of the loculi has been reported by Jackson (1933) for many other members of the family such as *Osmorhiza longistylis* and by Petersen (1911) in *Anthriscus silvestris*. In this part of the ovary each of the



FIGS. 12–24

FIGS. 12–24.—Figs. 12–23. Serial cross-sections of a flower from base upwards showing vascular supply to different floral organs. Figs. 16–18 show the inversion of the placental strand. Fig. 21 shows the supply of the ovules by the alternate ventral bundles in each carpel. Fig. 24. Cross-section of the entire inflorescence showing three flowers in different stages of development. PS = Placental strand. V = Ventral bundle. O.d. = Oil duct.

ventral bundles (V) gives off small branches which anastomose with the peripherals of the ovary 'wall'. The peripherals also fuse among themselves (Figs. 25–27). During this fusion a few small traces pass in and constitute the vascular supply of the disc (Figs. 26–31). The main bundles which correspond in position to the dorsals of the carpels also participate in this anastomosis and send a small branch each inwards which disappears abruptly in the region of the disc (Fig. 27).

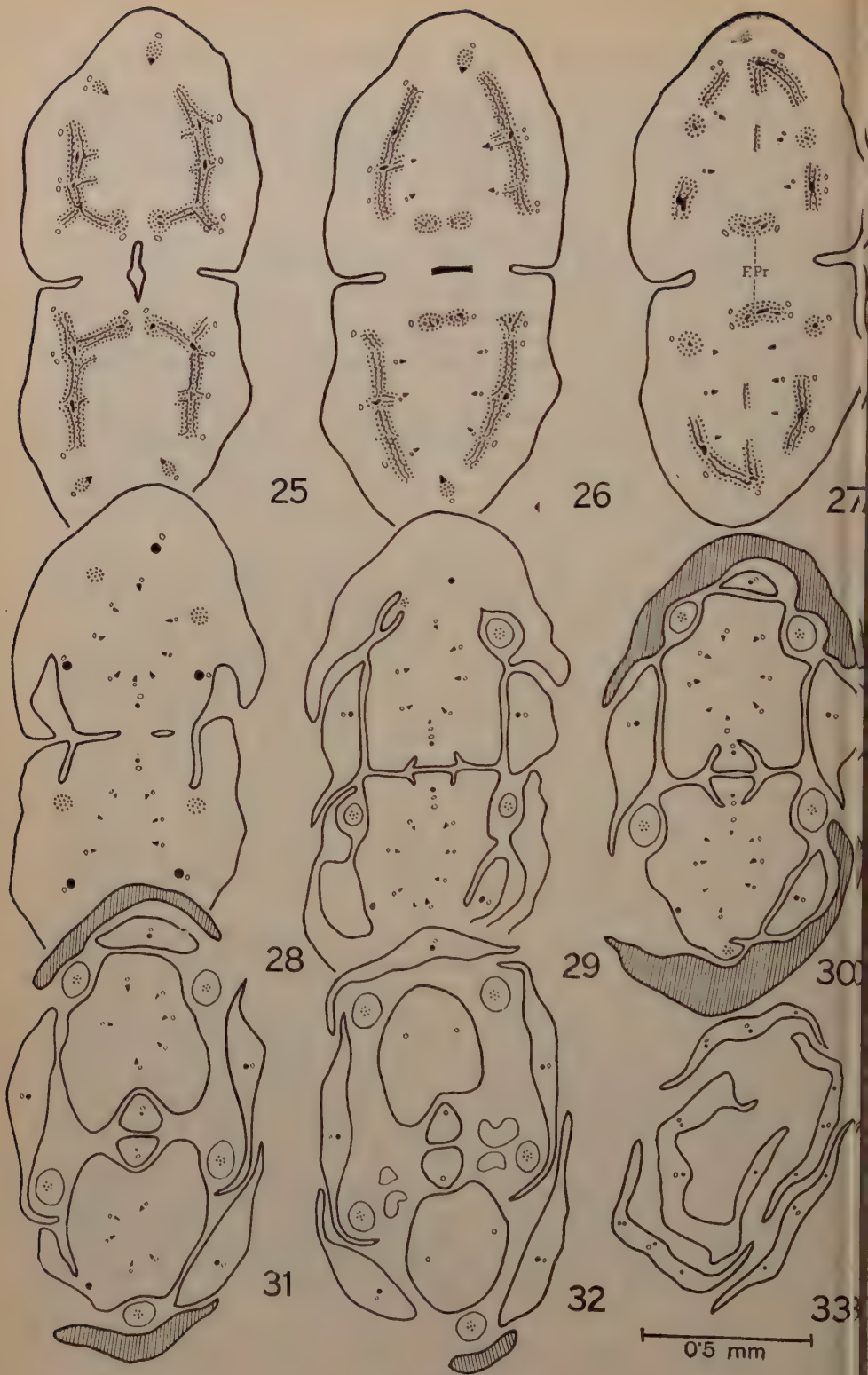
The two ventral bundles of each carpel, after the disappearance of the locules and before the differentiation of the floral organs, fuse together (Fig. 27). Each of these fusion products (F. Pr) gives a small branch to the style, and then the rest of it splits into small branches which get dispersed in the tissue of the corresponding half of the disc (Figs. 28–30).

Just before the differentiation of the floral organs there are ten traces in two groups of five each in the upper part of the ovary (Fig. 28). Five alternating ones of these pass outward and enter into the corresponding petals, where they divide into three each (Fig. 33). The remaining five traces which are mostly procambial pass out one each into the five stamens and traverse through them unbranched (Figs. 29–32). The small rim-like structure that separates outside the corolla does not receive any vascular supply whatsoever (Figs. 30–32).

The ovary 'wall' is clearly differentiated into two regions, the outer region which consists of several layers of compact parenchymatous tissue and the narrow inner region of small rectangular cells. The separation is effected by a special layer of cells containing white shinning crystals. The lining of the ovarian cavity consists of flattened, rectangular cells with prominent nuclei. These cells in fruits become somewhat columnar.

Hydrocotyle rotundifolia Roxb.—In the lower region of the peduncle the stele consists of two or three endarch unequal bundles. A little higher up it breaks up into as many bundles as there are flowers in a whorl which vary in number from four to six. One trace from each bundle passes out through the cortex of the peduncle and supplies the flower and its subtending bract. The bract bundle however, remains unbranched throughout. The remaining vascular tissue again organises into a dissected siphonostele. But it is soon broken up by traces for the second floral whorl. Whatever bundles are left behind in the peduncle supply the uppermost flowers.

The other bundle left after the separation of the bract trace divides and forms two distinct groups of vascular tissue as the ovary region is approached (Figs. 39, 40). Here these two bundles break up into about six bundles, two of which are lateral and four antero-posterior in position (Fig. 41). As the six bundles diverge out there are seen



FIGS. 25–33

FIGS. 25–33. Serial cross-section of a flower from base upwards showing vascular supply to different floral organs in continuation to Fig. 23. Fig. 27 shows fusion of two ventral bundles and small branches diverging in from the carpellary dorsals. F.Pr = Fusion product of the two ventral bundles. Rim portion stippled.

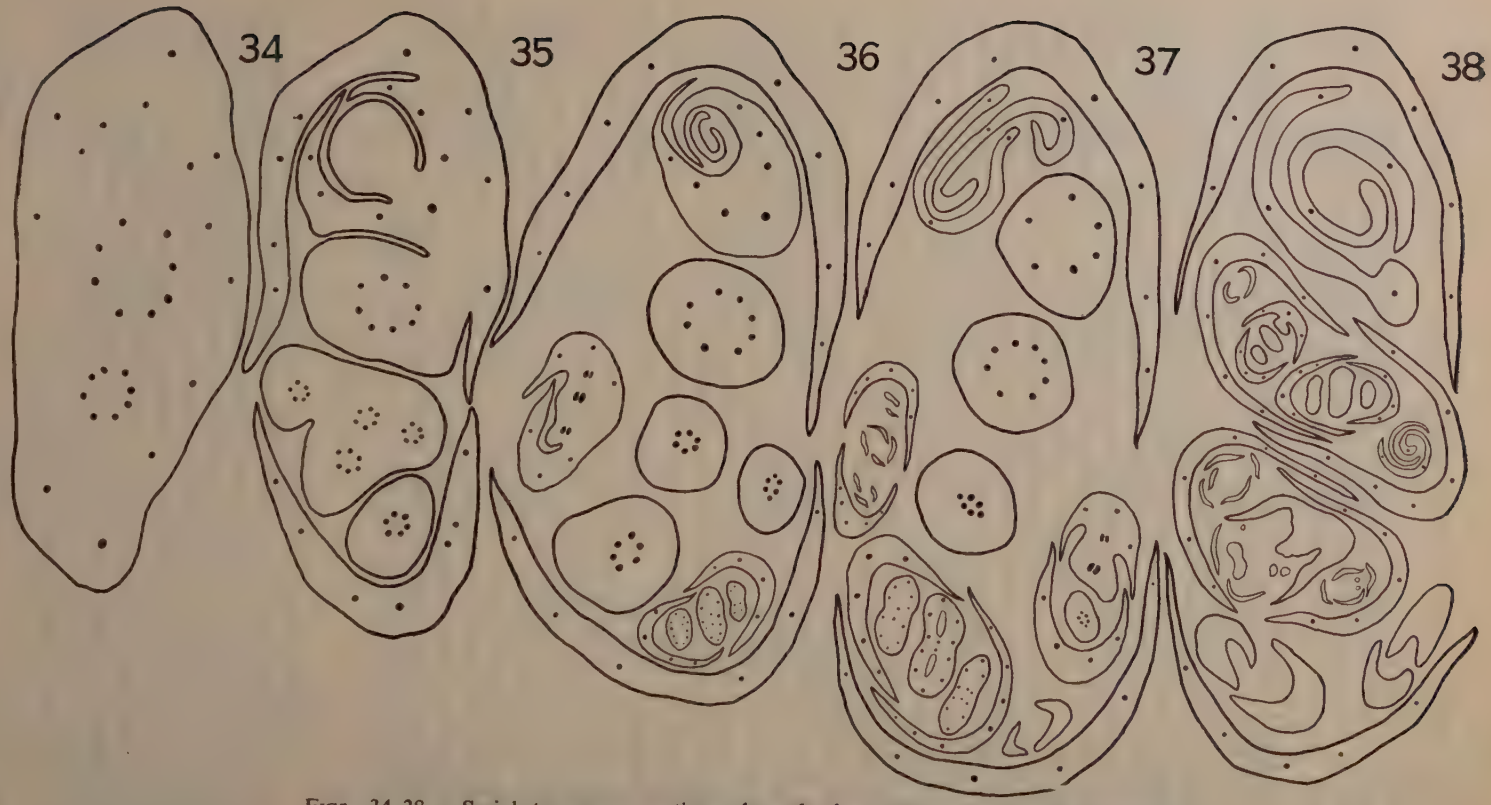
in the basal region of the ovary in *Hydrocotyle conferta* a few tracheidal cells, which die out within a couple of sections. Jackson (1933) also reports the occurrence of such xylem elements and she interprets it as evidence of the presence of a vestigial carpophore. The laterally situated bundles pass out and occupy median position in the corresponding carpellary valves (Fig. 42). The four bundles now left in the centre diverge out antero-posteriorly. Every one of them gives off a branch which passes out into the corresponding portion of the carpellary valves (Fig. 43). The four central bundles again split up into two each (Fig. 44). The outer of these send branches inward which on fusing in pairs furnish ovular traces (Figs. 45, 46, V). The portions left on the periphery supply the carpellary valves (Fig. 47, L″). In the meantime the other three bundles in the carpellary valves break up into two each more or less tangentially (Fig. 47). The outer of these together with the four antero-posterior bundles supply the petals and the stamens (Fig. 47), which are not shown in the figure.

Out of the ten inner bundles, five belonging to one carpel continue into the corresponding stylopodium where they disappear after some amount of anastomosis (Figs. 48–51). The uppermost parts of the stylopodia as well as the styles are without any vascular tissue (Fig. 52). In *Hydrocotyle conferta* all the five inner branches in each flower-half continue through the stylopodium into the style for a very short distance and in a very much reduced condition.

The 'wall' of the ovary in the lower portion of the flower is differentiated into two portions. The outer portion which consists of about four to six layers of thin-walled parenchymatous cells, is traversed by some oil ducts. Separating this region from the inner region of three to four layers is a layer of large parenchymatous cells which unlike the condition in *Centella asiatica* lack crystals. In *Hydrocotyle rotundifolia* some black irregular bodies are seen scattered here and there in the outer parenchymatous region of the ovary 'wall'. In *Hydrocotyle conferta* the outer portion becomes several layers thick at the level the ovules are attached to the placentæ.

DISCUSSION

The inflorescence.—One of the distinguishing characters of the family Umbelliferæ is its umbel inflorescence which may be simple or compound. *Centella asiatica* occupies a unique position in the family in this respect. Here the inflorescence consists usually of three laterally compressed flowers, the central one being the oldest. All the three flowers thus form a cyme which remains enclosed within a pair of large bracts forming the so-called involucre. The vascular supply of the inflorescence supports such an interpretation, for, the lateral flowers receive their traces almost simultaneously from the parent stele which directly enters the central flowers.



FIGS. 34–38. Serial transverse sections through the compound inflorescence axis.

As has been noted before, two instances of compound inflorescence were also seen in which the peduncle instead of bearing flowers bore four or five peduncles each of which in turn produced three flowers in the same way (Figs. 34–38). These are clear cases of compound cymes. The inflorescence in *Centella asiatica*, therefore, is a simple cyme although apparently and externally it is an umbel.

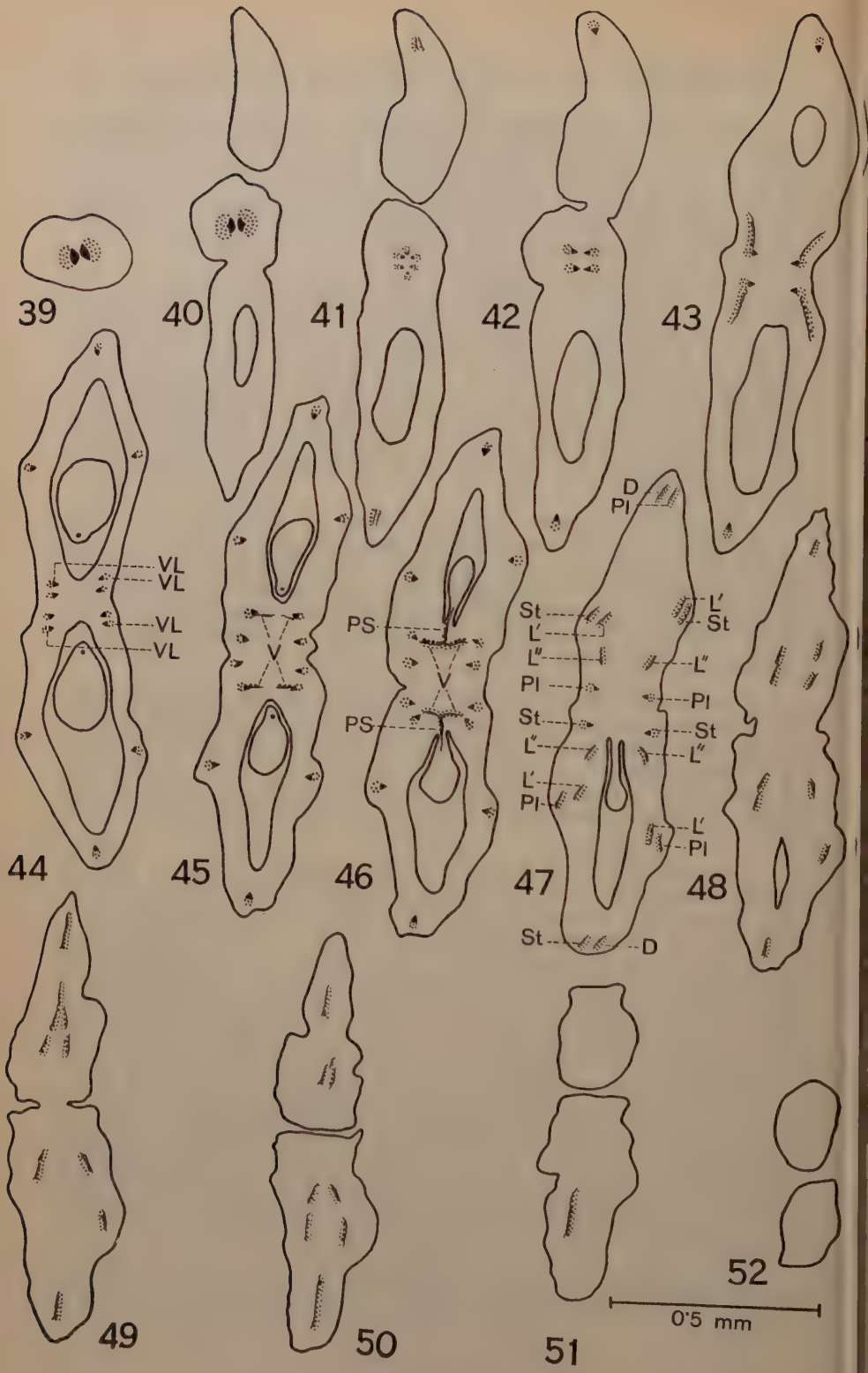
This fact led me to suspect if the many flowered inflorescence in the genus *Hydrocotyle* is not a compound cyme. But the facts turned out to be otherwise. The inflorescence in this genus is essentially racemose in character as the oldest flowers are arranged at the lowest level and the youngest at the top. As the flowers are arranged in whorls and separated by very short internodes the inflorescence of these two species of *Hydrocotyle* can best be described as 'umbellose raceme' or 'false umbel' although externally it appears to be an umbel, and has been described as such by almost all taxonomists (*cf.* Mathias and Constance, 1951).

The Gynœceum.—The behaviour and the course of vascular bundles in the ovary 'wall' of the species studied here do not throw any light on its morphological nature (*cf.*, Puri, 1952). But one thing deserves some attention. As will be recalled the ovary 'wall' in *Centella asiatica* is differentiated by a peculiar layer of crystal containing cells into an outer and an inner region. It may be that the region inner to the crystalline zone is carpellary in nature.

The Ventral Bundles.—The four bundles in the placental region of *Centella asiatica* are in all probability ventral bundles of the two carpels (*cf.* Fig. 19, V). This is borne out by their typical number, position, orientation and by the clear connection of these bundles with ovular supply. In the lower region of the ovary, for some distance, these bundles are fused in pairs into two placental strands (*cf.* Fig. 18, PS).

The condition in *Hydrocotyle* is, however, different. Jackson (1933) believes that in the Hydrocotyloideæ true ventral bundles of the carpels are lacking and that the ovules receive double vascular supply from the lateral bundles of the carpels. Such an interpretation does not appear to be convincing. It is apparent that the vasculature in the placental region in *Hydrocotyle* has suffered considerable reduction. I am inclined to believe that the branches marked V are the true carpellary ventrals which on fusing in pairs form the usual placental strands (PS). The latter pass out directly into the corresponding ovules. Such a condition where the entire placental strand passes out into the only ovule present has been described in quite a few cases *e.g.*, *Ranunculus* (Eames, 1931), *Juglans regia* (Nast, 1935). The portions of VL left on the periphery form the second pair of carpellary lateral (L″). Thus, we are of the opinion that in Hydrocotyloideæ the true ventral bundles are not lacking and that each ovule is supplied by a single placental strand which is the ultimate fusion product of the two ventral traces in each carpel.

The presence of the two ventral bundles in each of the ovule bearing region of the ovary in all the species studied here and other members


39
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48
49
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51
52
0·5 mm

FIGS. 39–52

FIGS. 39–52. Serial cross-sections of a mature fruit of *Hydrocotyle rotundifolia* from base upwards. Fig. 46. shows the formation of the placental strands by the fusion of two ventrals in each carpel. D = Dorsal bundle. Pt = Petal bundle. St = Stamen bundle. L′ = First pair of carpellary laterals. L″ = Second pair of carpellary laterals.

of the family (*cf.* Jackson, 1933) indicates that the two margins of each carpel are normal in so far as their anatomy is concerned. But functionally one of the alternate margins of each carpel has become sterile and bears no ovule in fully developed flowers. In other members of the family the other ovule is reported to be present in the beginning (Cammerloher, 1910; Jackson, 1933; Hakansson, 1952, etc.) which, however, aborts later on. But in *Hydrocotyle* and *Centella* the other ovule does not originate at all, and in this respect these two genera appear to be more reduced than other members of the family.

The Stylopodium.—The morphological nature of the stylopodium of the Umbelliferæ is an interesting problem. Henslow (1891) interpreted it as of carpellary nature as it is supplied by the placental bundles. Winkler (1941) regards the disc of the Umbelliferæ as appendages of the carpels rather than formation of the axis. Douglas (1944) reports Jackson (1933) as saying that the stylopodia represent the expanded bases of the styles. Although I could not find Jackson making any reference of this kind, such a conclusion is not supported by the present study. As will be recalled, in all the three species the stylopodia contain more vascular bundles than are usually present in the styles. The fact that the stylopodia have essentially the same vascular supply as the carpels appears to indicate that the disc in question is carpellary in nature. It seems perhaps that the sterile region of the ovary, which has grown up a little beyond the style bearing region, has, so to say, become solidified and taken to secretory function.

The Rim.—On the top of the ovary of *Centella asiatica* surrounding the petals and stamens there is a short annular rim which is conspicuous even in young flowers. This rim is not seen in the herbarium material of the two species of *Hydrocotyle*. This structure, which is non-vascular, appears to correspond to calyculus observed in certain Loranthaceæ (Singh, 1952; Maheshwari and Singh, 1952). It will be recalled that the rim appears to be better developed alternating with petals. This feature seems to indicate that the annular rim of *Centella asiatica* may be calycine in nature. Hooker (1879) and Fernald (1950) have perhaps referred to this when they described the calyx in this species as vestigial and obsolete.

Relationships.—Cammerloher (1910), Petersen (1911), Jackson (1933) and Hakansson (1952) have reported two anatropous ovules in each loculus of a young umbellifer ovary; one of these is erect and usually aborts, the other is pendulous and develops to maturity. But Cammerloher, Petersen and Hakansson could find no trace of the aborted ovule in various species of *Hydrocotyle* (*H. repanda*, *H. vulgaris*, etc.) studied by them even in the early stages of the flower development. I also could not find out any trace of the aborted ovule in *H. rotundifolia* and *H. conferta*. Cammerloher is said to have reported the lacking of the upper aborted ovule in several species of the Araliaceæ

(*cf.* Petersen, 1911). On the basis of this similarity between *Hydrocotyle* and some species of the Araliaceæ Petersen (1911) supports the transfer of *Hydrocotyle* to the Araliaceæ. But *Didiscus*, a related genus of *Hydrocotyle*, has two ovules, the upper one being difficult to observe as it is jammed in the mericrap tissue. In view of this Hakansson (1952) has suggested that the absence of the aborted ovule in *Hydrocotyle* cannot be interpreted as an araliacean affinity. The same author has also reported the resemblance of *Hydrocotyle* with other Umbelliferæ in having a monosporic and eight-nucleate embryo-sac. *Hydrocotyle* also resembles *Didiscus* and *Actinotus* of the Umbelliferæ and some members of the Araliaceæ in having hairs on the upper side of the funiculus but differs from other members of the Umbelliferæ in this character. It, however, differs from *Didiscus* and *Xanthosia*, the other members of the tribe Hydrocotyleæ, in the size of the nucellus and the number of embryo-sac mother cell; and is an exception along with *Eryngium* in the Umbellifræ in the general occurrence of polyploidy (Hakansson, 1953).

As will be recalled *Hydrocotyle* lacks some of the important characters of the Umbelliferæ in the external morphology and also has a significantly different vascular plan for the flower. All this seems to be connected with the absence of a carpophore in *Hydrocotyle*. Thus, *Hydrocotyle* shows resemblances as well as differences from other members of the Umbelliferæ. No doubt it also resembles Araliaceæ in some of the characters. But taking all things into consideration the separation of *Hydrocotyle* into a separate sub-family of the Umbelliferæ as has been done by Engler-Prantl and others seems to be justified.

Centella also lacks some of the important characters of the Umbelliferæ, *e.g.*, the upper aborted ovule, the umbel inflorescence, compound leaves with sheathing leaf-bases, hollow internodes, carpophore in mature fruit and thus resembles *Hydrocotyle* in these respects. But the separation of *Hydrocotyle asiatica* as *Centella asiatica* has been done by most of the authors on fruit characters only. This separation is very well supported by the present study as *Centella* differs from *Hydrocotyle* in many characters, *e.g.*, the type of inflorescence, the vascular supply of inflorescence, bracts, ovary 'wall', ovules, stylopodia and styles.

Summary

External morphology and vascular anatomy of the flower of *Centella asiatica* and two species of *Hydrocotyle* have been described.

The inflorescence in *Centella* is a cyme while in *Hydrocotyle* it is an ' umbellose raceme'.

Each ovule is having its vascular supply from one alternating ventral bundle in each carpel in *Centella*, while in *Hydrocotyle* it is supplied by the placental strand, the fusion product of the two ventral traces.

Centella and *Hydrocotyle*, both lack the upper aborted ovule unlike other members of the Umbelliferæ. They also lack the carpophore, which is a special structure of the mature fruit of the other Umbelliferæ.

The disc or stylopodium is carpellary in nature and is believed to be formed by the upper sterile region of the carpel.

Styles are supplied by branches of the fusion products of the ventral bundles in *Centella*.

The annular rim of *Centella* is believed to be calycine in nature.

The present anatomical study justifies the separation of *Hydrocotyle asiatica* into *Centella asiatica* and supports the retention of these two genera in a separate sub-family Hydrocotyloideæ of the Umbelliferæ.

Acknowledgements

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ECOLOGICAL FACTORS GOVERNING THE DISTRIBUTION OF SOIL MICROFUNGI IN SOME FOREST SOILS OF SAGAR*

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(With one Map and two Figures)

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Introduction

The area selected for study is a part of forest neighbouring Sagar Town on the eastern side which is known as Patharia forest. It is about 3 miles long and $2\frac{1}{2}$ miles wide and consists of numerous small plateux, slopes and valleys surrounded by grasslands and agricultural lands (Map, Fig. 1).

The site for the study was selected because of a number of interesting features discernible in a small compact area from the point of view of geology, topography, soil types and the variety of fungal flora as will be seen in the accounts to follow.

This forest was previously studied by Misra and Joshi (1952) with respect to the higher vegetation. They collected and studied general data on climate, geology, soil characteristics, physiographic and biotic factors operating in the area and correlated them with 7 types of forest plant communities recognised by them.

Climate

General.—Sagar is situated in north of the Madhya Pradesh State at a latitude of 23·50 N and longitude 78·50 E. The average height above sea level is 2,000 feet. The climate is typically monsoonic which supports a 'Tropical Dry Deciduous' type of forest. The average annual rainfall is 48 inches the bulk of which falls during the rainy season from June–September. During the rainy season about 7 inches are received in June, 16 inches in July, 12 inches in August, 7–8 inches in September and about 1 inch in October. The rest of the 7 months put together account for only about 3 inches, most of which falls during the months of December and January and hence called winter rains.

Soil Temperature.—The record of soil temperature could not be kept throughout the period of investigation. The soil thermograph was received in October 1953 and from that time onwards a regular record was kept. The data of soil temperatures, taken at a depth of

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* Part of a thesis approved for the degree of Doctor of Philosophy by the University of Saugar.

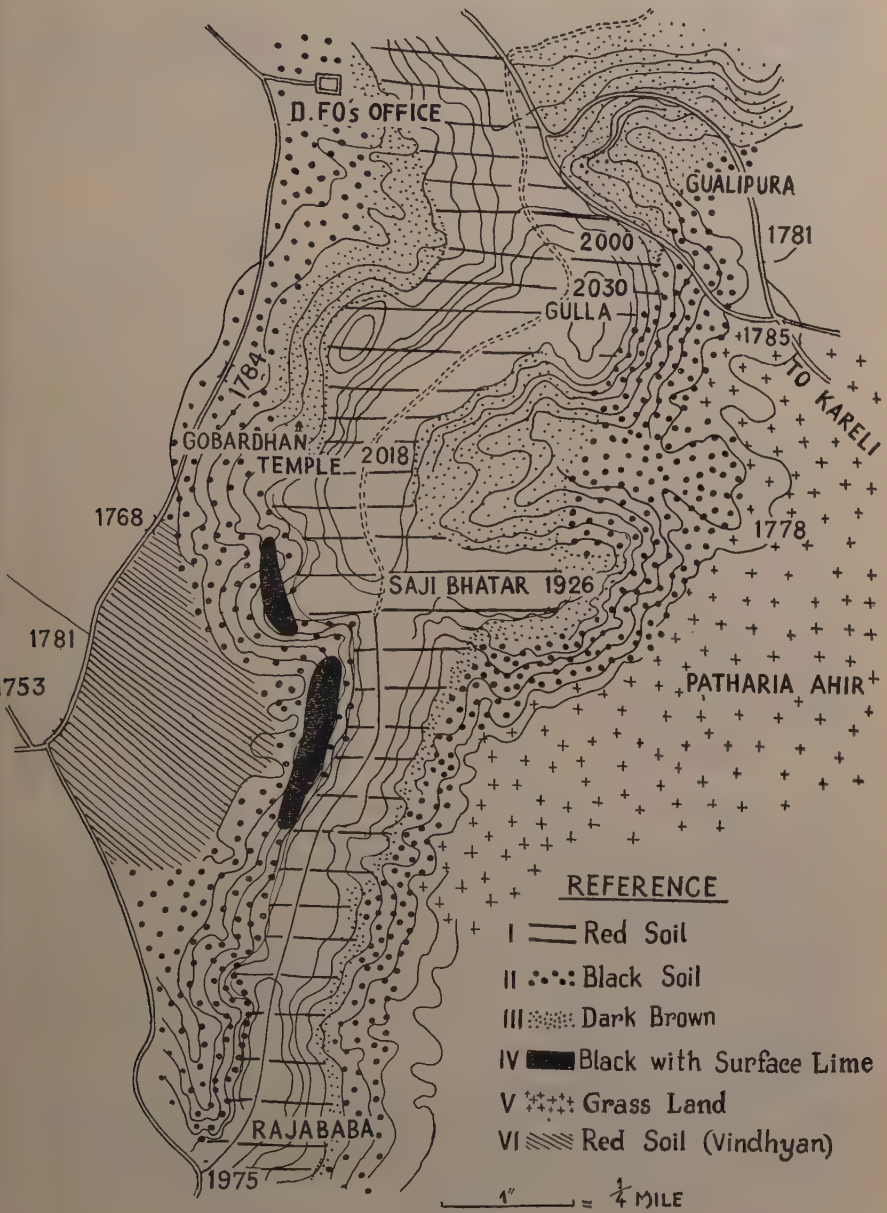

FIG. 1. Soil and Contour Map of Patharia Forest.

6 inches, are given in the following table. The soil temperatures were found to be generally 10–15° F. above the air temperatures in shade. During summer months the soil temperature reached up to 50° C. which is obviously unfavourable for the growth of fungi.

Soil Temperatures at a Depth of 6 inches

Month	Minimum	Maximum
October, 1953 ..	23°	33° C.
November, 1953 ..	18°	35° C.
December, 1953 ..	18°	31° C.
January, 1954 ..	15°	30° C.
February, 1954 ..	17°	32° C.
March, 1954 ..	20°	40° C.
April, 1954 ..	26°	46° C.
May, 1954 ..	29°	50° C.
June, 1954 ..	30°	50° C.
July, 1954 ..	26°	37° C.
August, 1954 ..	27°	37° C.
September, 1954 ..	25°	36° C.

Seasons.—The year is divided into 3 seasons, *viz.*, rainy, winter and summer. The rainy season starts by the middle of June and ends by the end of September. The typical month is August when the mean minimum temperature is 72° F. and the mean maximum is 81·2° F. The rainy season is followed by the winter which lasts up to the end of February, the mean temperature during December being 76·1° F. and the minimum 54·3° F. The rainfall is scanty during winter and the period is generally dry. Frosts may occur during this period, especially in the valleys.

The summer season starts with March and lasts till the onset of rains. It is marked by hot north-westerly winds and a blazing sun which parches the lands. The hottest month is May when the average maximum temperature is 106·3° F. and mean temperature is 83·1° F.

Geology

The substrata of Patharia Hills consist of basalt overlying sandstones. These were formed by the close of the cretaceous period by a series of lava flows and are known as Deccan trap. The basaltic rocks at places are seen traversed by beds of lime, clay and ashes.

These inter-trappean beds originated during the intermittent periods between two successive volcanic eruptions and are mostly lacustrine in origin. Besides the trap rocks which cover the majority of the area, the Patharia Hills show an outcrop of Vindhyan sandstones on the south-westerly side. This presents an interesting contrast between the resultant soils from these two different types of parent rocks.

Soils

Broadly speaking the area is covered with two main types of soils formed from the trap mass. One is of red colour and is usually found on the plateux and upper parts of the slopes. The second is black in colour and occupies the valleys and lower parts of the slopes. Intergrading types between these, with various local modifications, are frequently met with.

The red soils (lateritic in a general sense) covering the plateux are produced under good drainage conditions. The silica which is dissolved in the rain-water is quickly drained off leaving the sesquioxides behind. The ferric oxide which is left off in the residual soil gives it the characteristic red colour. The soil has a low base status since the bases are washed away along with the rain-water. In spite of the fact that the soil is poor and deficient intrinsically due to low silica sesquioxide ratio, it has been found to support a good vegetation. On analysis it is found to possess a good amount of organic matter and a fair degree of nutrient level. This is due to the fact that the well drained condition with consequent good aeration provides favourable circumstance for the microbiological activity in the soil and the litter which falls to the ground is quickly decomposed to release mineral nutrients to the standing cover of vegetation.

The second type of soil which is black in various shades differs markedly from the above type though derived from the same parent rock. It is found in valleys, bases of hills, lower slopes, ditches and other lowlying areas. Drainage in these situations is not so good and the water which collects in such locations is charged with bases and silica. There is more of surface leaching than loss due to run off. The soils are rich in bases and organic content though the drainage and aeration is comparatively poor. The black soils are known as the " Black cotton soils " or " Regur ". They are often referred to as Chernozems (black earths) though they differ radically on grounds of pedology from the chernozems of other parts of the world. The Indian ' regurs ' develop under a tropical monsoonic climate characterised by temperatures always much above the freezing point and a long dry period following the rainy season. Decomposition of organic matter is very rapid under such conditions.

Incidentally enough, in the area under consideration, we find trap rocks giving rise to lateritic soils at the higher levels and regur at the base with various degrees of admixtures determined by topography and drainage.

Soil Types and Selection of Spots for Detailed Study

The abovementioned two basic types of soils are further modified by such factors as the drainage, topography, erosion, biotic influences, type of vegetation, etc. Sample surveys of the entire area were carried out to delimit the various types of soils and finally the following 7 types of soils, which were quite characteristic, were selected for detailed investigations. These are shown on the map (Fig. 1) and are as follows:

(1) Typical red soil on the plateau near Raja Baba.

(2) Typical black soil near the base of the hill on the south-east of Saji Bhatar.

(3) Brownish-black soil on the mid-slope near Kareli Road.

(4) A belt on the mid-slope on a west ridge where lime gets deposited on the surface. This lime is brought by underground water currents which, after passing through the inter-trappean lime beds, comes out in the form of springs during rains. There is a long belt of such soil as shown on the map.

(5) A grassland soil on the south-east of the hills near Patharia Ahir, typical of the soils which surround the Patharia Forest.

(6) Red soil on the outcrop of Vindhyan sandstones which are contiguous with the trap rocks on the south-westerly side of the Patharia Forest.

(7) A typical spot in Ghatera Forest—a spot about 60 miles from Sagar where the forest is on alluvial soil. This was studied as a contrasting type since it constitutes another of the typical forest soils of Sagar.

The sites selected for study on these different types of soils are shown on the contour map of Patharia Forest (Fig. 1).

Methods of Study

Collection of Soil Samples.—The actual spot for collecting soil was chosen carefully taking into consideration the drainage, degree of erosion, ground cover, proximity to trees and such other factors which were likely to effect the soil in comparison with the type it was intended to represent.

After selecting the spot, a pit 3 feet long, 3 feet wide and 3 feet deep was dug. The faces of the pit were carefully examined to record any visible stratification. The general physical nature of the soils of different strata whether clayey, sandy, loamy, etc.; the colour, the presence of boulders, rubbles, lime concretions or any other remarkable features were recorded. One of the faces of the pit was cleared carefully first with a small spade and finally scraped with a sterilised broad spatula. The surface litter on the side of the selected face was cleared but care was taken not to remove the well formed humus and grass roots embedded in the top layer of the soil. The first sample was taken to represent the top 6 inches of the profile. The second was taken from the next 6 inches (7–12 inches) and the third from further next

6 inches (13–18 inches) deep, by cutting steps in the pit face and removing soil from the desired depth. Care was taken to scrape the face of the pit by a sterilized spatula just before the actual collection so that the contamination of one soil with the other was avoided. The samples were packed in sterilized containers and brought to the laboratory, the soils were numbered serially and in addition the marks S_1, S_2 and S_3 were put in parenthesis for the top, middle and bottom soils respectively. This notation was maintained throughout and has been adopted in the text.

Soil Tests and Analyses.—The soil was tested and analysed for various characters and exhaustive data were recorded comprising of pH value, moisture content, water-holding capacity, carbon content, organic content, total nitrogen, nitrate, phosphate, exchangeable calcium, potassium and iron.

Moisture content, water-holding capacity, exchangeable calcium, iron and potassium were determined by the methods outlined by Piper (1944). Determination of nitrate was done by phenol-disulphonic acid method as recommended by Harper (1924). Carbonates were estimated by Collin's Calcimeter according to the modified method by Shah and Amin (1951) and total available phosphates were extracted by CO_2 in a 2% soil suspension as suggested by Puri and Asghar (1936) and blue colour was developed by the stannous chloride method of Chapman (1932). Organic carbon and nitrogen were determined by Robinson's and Kjeldahl's method respectively. Total organic content was calculated by multiplying the quantity of organic carbon by 1·724 (Robinson, 1952). The determination of pH was done by PYE pH meter.

Record of Fungal Flora.—The fungal flora was studied by the dilution plate method of Waksman (1927). In three 150 c.c. flasks three dilutions, *viz.*, 1: 100, 1: 1,000 and 1: 10,000 were prepared. From these 3 suspensions, 1 c.c. portions were transferred to sterilized Petri dishes and a tube of melted agar cooled to about 42° C. was added to each. Waksman's agar (Waksman, 1927) was used for platings. Six parallel plates were poured for each dilution so that for each depth 18 plates were poured and for one soil sample of S_1, S_2 and S_3, $18 \times 3 = 54$ plates were prepared. The plates were incubated at about 25° C. for 5–8 days. Observations were recorded at least twice, first when the overgrowing flocculent types such as Mucorales, *Trichoderma*, etc., had not made excessive growth to interfere with observation of other species and a second time when these had come to an advanced stage to enable identification. Often, very slow-growing ones had to be cut and replanted in different poured dishes for the purpose of further growth in order to save them from being overrun by the more aggressive types. A complete record of data both of the number of colonies in each plate, the species present, and the number of colonies of each species were kept.

Replications.—In each of the 7 types of soils 3 pits were dug and data on fungal flora and soil analyses were recorded in the aforesaid manner. In this way in all 7 (types of soils) $\times 3$ (depths) $\times 3$ (replications) $= 63$ soil samples were studied.

Number of Fungi.—From the number of colonies counted in each plate, the number of fungi in 1 gm. of soil was calculated. A correction was applied on the basis of the moisture present in the soil (*vide* soil data Table I) so that figures express the fungi per gm. of dry weight of soil. Average for each sample and general averages for different depths (S_1, S_2 and S_3) of the same type of soils were calculated.

Isolation of ' Water Moulds '.—A small quantity of soil from each sample was placed in a Petri dish containing sterilized water and a few boiled hemp seeds were placed as baits. Aquatic forms grew in a few days time. They were isolated and studied by the usual methods.

Isolation and Purification of Fungi.—When a species was seen for the first time it was transferred to other dishes or slants for the purpose of purification. Single spore isolation was done by one of the usual methods, in all cases, to ensure complete purity of culture before final description was undertaken.

Phytosociological Methods

The vegetational analysis of the tree flora was done by studying and recording the details of vegetation in quadrats 25×25 feet in size. The frequency, abundance and dominance were calculated and expressed as per following scale (Braun Blanquet, 1932; Misra and Joshi, 1952) from the data recorded for 20 quadrats for each type of soil.

Frequency.—Percentage occurrence of a species in the units was calculated in the usual manner and frequency classes were expressed on 1–5 scale as follows:—

Class 1 ..	Species occurring		1– 20%	of the quadrats
Class 2 ..	„	„	21– 40%	„
Class 3 ..	„	„	41– 60%	„
Class 4 ..	„	„	61– 80%	„
Class 5 ..	„	„	81–100%	„

Abundance.—Numerical abundance was calculated from the tree counts on the following scale:—

Class 1 ..	Species forming		1– 3%	of the trees
Class 2 ..	„	„	4– 8%	„
Class 3 ..	„	„	9– 15%	„
Class 4 ..	„	„	16– 25%	„
Class 5 ..	„	„	26–100%	„

Dominance.—It was estimated according to the spread of the crown of the species and expressed on the following scale:—

Class 0 ..	Covering less than		1%	of the ground
Class 1 ..	„	„	1– 5%	„
Class 2 ..	„	„	6– 10%	„
Class 3 ..	„	„	11– 20%	„
Class 4 ..	„	„	21– 40%	„
Class 5 ..	„	„	41–100%	„

It was found more convenient to slightly modify the scale for noting the abundance, from that adopted by Misra and Joshi (1952).

Determination of Frequency, Abundance and Total Number of Fungi in each Soil Type.—As noted earlier, 6 Petri dishes were plated for each dilution of a sample. For the purpose of noting the number of colonies and determining the frequency and numerical abundance of various fungi, observations were recorded from 6 Petri dishes of the second dilution (1 : 1,000) in case of top soils (S_1) and of first dilution (1 : 100) in the case of bottom soils (S_3); in the case of S_2 soils first or second dilution plates were used depending upon the average number of colonies per plate. In short, plates of that dilution were chosen for computation which gave about 20–50 colonies per plate, since it was found by experience that it gave the information about all the species in a well represented manner. Each Petri dish was treated as a unit of study and analogous to a quadrat in a forest. In this way, since there were 3 replications, these results were presented by averaging the figures for the 18 Petri dishes plated for each horizon of a soil profile.

The same classes for the expression of frequency and abundance were used as given above for the higher flora. Dominance was not calculated for obvious reasons in case of fungi.

Presentation of Data

The details of results on the basis of average values for S_1, S_2 and S_3 horizons of each type of soil are given in Table I.

(1) *Occurrence of Species of Fungi in Various Soils.*—The occurrence of different fungi in the various horizons of different soil types is presented elsewhere in the text.

(2) *Phytosociological Analysis of Vegetational Cover and of Fungal Flora along with Important Soil Characteristics of Various Soil Profiles.*—These data are given from pages 271–283.

TABLE I

Data on Samples of Soils (Based on Average of Three Samples)

Locality	Soil type	Horizon	Moisture content %	Water holding cap. %	pH	Organic carbon content %	Organic matter %	Total nitrogen %	Nitrate content in mg. per 100 g. of soil	Phosphate content parts per million	Carbonate content %	Exch. potassium in mg. per 100 g. of soil	Exch. iron parts per million	Exch. calcium %	No. of fungi per g. of soil
Plateau near Raja Baba	I	S_1	11·6	60·4	6·5	1·33	2·30	0·11	4·0	5·0	Trace	103	5·0	0·43	46,890
		S_2	13·2	58·8	6·5	1·12	1·93	0·05	1·5	5·0	do	103	4·8	0·41	7,490
		S_3	17·7	54·6	7·0	0·59	1·03	0·03	Tr.	3·6	do	102	4·5	0·24	5,450
Base of hill (Saji Bhatar)	II	S_1	10·7	60·3	7·2	1·81	3·15	0·15	3·0	5·7	do	101	3·9	0·50	39,990
		S_2	11·5	58·3	7·2	1·21	2·08	0·08	1·0	5·7	do	101	3·8	0·47	15,540
		S_3	20·0	57·7	7·2	0·85	1·47	0·06	0·5	5·0	do	94	3·6	0·47	3,790
Mid-slope (near Kareli Road)	III	S_1	18·36	61·8	7·7	2·06	3·56	0·13	5·3	5·7	6·28	106	3·5	5·45	1,04,050
		S_2	13·07	59·1	7·5	1·38	2·38	0·08	3·5	3·0	1·15	105	3·5	3·10	46,020
		S_3	16·97	59·0	7·0	1·05	1·97	0·06	3·1	3·0	0·51	95	3·7	0·88	14,160
Mid-slope (West ridge)	IV	S_1	14·9	55·7	8·0	1·63	2·81	0·11	4·0	5·0	7·00	113	2·8	2·12	56,280
		S_2	11·9	52·5	7·7	0·81	1·40	0·08	1·5	5·0	1·96	123	2·3	0·66	16,600
		S_3	14·1	49·9	7·7	0·51	0·87	0·03	1·5	5·0	1·13	119	2·5	0·46	2,290
Grassland	V	S_1	10·9	63·3	7·0	2·37	4·10	0·11	1·8	5·7	1·01	130	3·1	0·87	70,520
		S_2	15·1	62·8	7·7	1·16	2·00	0·07	1·0	5·0	4·40	150	2·7	4·86	26,160
		S_3	19·2	56·8	7·7	0·88	1·52	0·04	1·0	5·0	30·16	128	2·8	11·33	9,760
Vindhyan outcrop	VI	S_1	8·9	42·9	6·4	1·28	2·22	0·12	2·5	5·0	Trace	134	2·8	0·14	15,610
		S_2	7·7	40·7	6·7	0·97	1·68	0·10	1·8	4·3	do	135	3·0	0·11	10,570
		S_3	8·2	38·8	6·8	0·89	1·54	0·09	0·8	3·0	do	131	2·9	0·09	680
Ghatera Forest	VII	S_1	15·00	50·0	7·5	1·29	2·22	0·17	4·0	6·3	0·54	215	3·6	1·33	54,920
		S_2	11·36	45·3	7·5	0·63	1·08	0·07	1·8	5·0	0·83	160	3·2	1·09	9,530
		S_3	9·06	42·2	7·5	0·43	0·74	0·05	1·2	5·0	1·07	180	3·1	0·85	5,810

Soil Type I. Red Soil on Plateau near Raja Baba

Surface vegetation.—The ground is covered with rich vegetation. The following table gives the analysis for trees and big shrubs.

Sl. No.	Name of species*	Frequency	Abundance	Dominance
1	*Anogeissus latifolia* Wall. ..	5	4	3
2	*Nyctanthes arbotristis* Linn. ..	4	4	3
3	*Tectona grandis* Linn.f.	3	3	3
4	*Diospyros melanoxylon* Roxb. ..	3	3	1
5	*Terminalia tomentosa* Bedd. ..	3	2	1
6	*Saccopetalum tomentosum* HK.f. &T.	2	2	1
7	*Emblica officinalis* Gaertn. ..	2	2	1
8	*Zizyphus xylopyra* Willd. ..	2	1	1
9	*Carissa spinarum* Linn.	2	2	0
10	*Kydia calycina* Roxb.	1	1	2
11	*Lagerstræmia parviflora* Roxb. ..	1	1	1
12	*Butea monosperma* O.Ktze. ..	1	1	1
13	*Gardenia latifolia* Ait.	1	1	1
14	*Wrightia tinctoria* Br.	1	1	0
15	*Buchanania lanzan* Spreng. ..	1	1	0
16	*Flacourtia ramontchi* L'Her ..	1	1	0
17	*Bridelia retusa* A. Juss.	1	1	0
18	*Zizyphus œnoplia* Mill.	1	1	0

* The authorities for naming higher plants are given when the name occurs for the first time either in table or in the text.

The most important trees constituting this forest are *Anogeissus latifolia, Nyctanthes arbotristis, Tectona grandis, Diospyros melanoxylon* and *Terminalia tomentosa.* In addition there are large number of other tree species in varying proportions. It appears that the type of soil supports a forest which has climax or near climax vegetation.

Physical Characteristics.—The ground surface is covered with freshly fallen litter followed below by progressively decomposed layers of leaf mould.

S_1 (top 6 inches)—Dark red in colour, sandy, friable, somewhat gritty. Water-holding capacity is high.

S_2 (7–12 inches)—Red but lighter in shade than S_1; much more gritty with coarser particles.

S_3 (13–18 inches)—Yellowish red, partially weathered sub-soil mixed with pieces of small stones, pebbles, etc.

Chemical Characteristics.—The soil is slightly acidic, the pH is 6·5 in the upper two layers and 7·0 in the S_3. Organic matter is fairly

high. Exchangeable calcium in spite of good surface drainage is not low, being about 0·4% in the S_1 and S_2 and 0·24 in the S_3 horizon. This appears to be due to a good amount of litter which is added to soil every year. The soil is coarser and is very well aerated so that humification is rapid. The values for exchangeable bases are low, indicating that surface leaching is not much and the bases are washed away rather than leached down.

Fungal Flora

(i) Average number of fungi per gram of dry soil: (S_1)—46,890; (S_2)—7,490; (S_3)—5,450.

(ii) Species recorded:

Sl. No.	Name of Species*	S_1		S_2		S_3	
		F.	A.	F.	A.	F.	A.
1	*Absidia spinosa*	5	3	4	3	2	1
2	*Rhizopus nigricans*	2	2	..	..	..	..
3	*Cunninghamella bertholletiæ* ..	2	2	..	..	..	..
4	*Trichoderma lignorum* ..	5	3	4	4	4	4
5	*Aspergillus fumigatus* (str. 1) ..	3	2	..	..	..	..
6	*A. ustus*	3	2	..	..	..	..
7	*A. flavipes*	2	2	..	..	..	..
8	*A. versicolor*	2	1	2	2	..	..
9	*A. niger* (str. 1)	5	4	2	4	2	3
10	*A. niger* (str. 2)	2	1	..	..	..	..
11	*Penicillium nigricans* ..	3	3	2	3	..	..
12	*P. lilacinum*	5	3	3	4	3	2
13	*Gliocladium deliquescens* ..	3	2	2	3	..	..
14	*G. roseum*	2	1	..	..	..	..
15	*Curvularia lunata*	2	2	..	..	..	..
16	*Fusarium nivale*	3	3	2	4	3	5
17	*Fusarium* sp.	3	3	2	2	2	3

* The authorities for all bionomials of fungi are as given by Gilman (1945), Raper and Thom (1949) and Thom and Raper (1945).

F. = Frequency; A. = Abundance.

Outstanding Features of Fungal Flora.—As will be seen from the figures, the total number of fungi goes on decreasing with the increasing depth. The number of species also falls in a like manner. *Absidia spinosa*, *Trichoderma lignorum*, *Asperiglus niger*, *Penicillium lilacinum* and species of *Fusarium* are the preponderant ones which have a good distribution throughout the profile. *Rhizopus nigricans*, *Cunninghamella bertholletiae*, *A. fumigatus* (str. 1), *A. niger* (str. 2), *A. flavipes*, *A. ustus* and *Gliocladium roseum* along with *Curvularia lunata* were found only in the top soil.

Soil Type II. Black Soil at the Base of the Hill on the South-East of Saji Bhatar

Surface Vegetation.—The vegetational cover is fair though not so rich as in the soil type I. During summer the ground is rather sparsely shaded and soil gets parched. The following table gives the analysis for the trees and big shrubs.

Sl. No.	Name of Species	Frequency	Abundance	Dominance
1	*Tectona grandis*	5	5	4
2	*Diospyros melanoxylon*	3	4	1
3	*Butea monosperma*	3	3	1
4	*Anogeissus latifolia*	3	2	1
5	*Terminalia tomentosa*	2	2	1
6	*Lannea grandis* Engler	2	2	1
7	*Kydia calycina*	1	1	1
8	*Lagerstræmia parviflora*	1	1	1
9	*Carissa spinarum*	1	1	0
10	*Aegle marmelos* Corr.	1	1	0
11	*Acacia catechu* Willd.	1	1	0
12	*Flacourtia ramontchi* ..	1	1	0

Tectona grandis is the most dominant species followed by *Diospyros melanoxylon, Butea monosperma* and *Anogeissus latifolia.* The presence of species of *Flacourtia* and *Acacia* would indicate that the forest has not reached the climax stage.

Physical Characteristics—The ground surface is covered with a fair amount of litter.

S_1 (top 6 inches)—Dark black in colour, clayey loam, sticky, prominent cracks on drying. Water-holding capacity is high.

S_2 (7–12 inches)—Greyish black (lighter than S_1), small pieces of stones and pebbles irregularly mixed up, coarser than S_1, slightly gritty to touch.

S_3 (13–18 inches)—Greyish in colour, consists mostly of the partially weathered parent rock.

Chemical Characteristics.—The outstanding features are a high degree of pH ranging from 7·0–7·5, rich in organic content, nitrogen content and exchangeable bases. The bases are well distributed throughout the profile.

Fungal Flora.—

(i) Average number of fungi per gram of dry soil:

(S_1)—39,990; (S_2)—15,540; (S_3)—3,790.

(ii) Species recorded:

Sl. No.	Name of species	S_1		S_2		S_3	
		F.	A.	F.	A.	F.	A.
1	*Absidia spinosa*	4	3	..	..	..	..
2	*Rhizopus nigricans*	4	2	..	..	..	..
3	*R. nodosus*	1	1	..	..	..	..
4	*Cunninghamella bertholletiæ* ..	3	2	..	..	..	..
5	*C. verticillata*	3	1	..	..	..	..
6	*Chætomium* sp.	3	1	..	..	..	..
7	*Phoma hibernica*	3	2	4	4	4	5
8	*Cephalosporium acremonium* ..	4	3	..	..	..	..
9	*Trichoderma lignorum* ..	5	3	..	..	..	..
10	*Aspergillus fumigatus* (str. 1) ..	..	..	3	4	..	..
11	*A. fumigatus* (str. 2)	3	2	..	..	..	..
12	*A. sydowi*	2	1	..	..	..	..
13	*A. terreus*	4	3	..	..	..	..
14	*A. candidus* (str. 1) ..	4	3	3	3	2	2
15	*A. candidus* (str. 2)	3	1	..	..	..	..
16	*A. niger* (str. 1)	5	3	4	4	3	4
17	*A. niger* (str. 2)	3	1	..	..	..	..
18	*Aspergillus flavus*	3	2	4	3	..	..
19	*Penicillium nigricans* ..	3	2	..	..	..	..
20	*Pœcilomyces varioti*	2	2	..	..	..	..
21	*P. fusisporus* sp. nov. ..	2	2	..	..	..	..
22	*Hormodendrum cladosporioides*	4	3	..	..	..	..
23	*Fusarium nivale*	3	2	4	4	4	4

Outstanding Features of Fungal Flora.—As in type I the number of fungi and also the number of species fall rather abruptly with the depth. *Absidia spinosa*, *T. lignorum*, *Aspergillus niger*, *A. terreus*, *A. candidus* (str. 1), *Hormodendrum cladosporioides* and *Cephalosporium acremonium* were the most preponderant in S_1 horizon. There were only 6 species found in S_2 and 4 in S_3 horizon. *Pœcilomyces fusisporus* a new species was discovered from the top horizon.

Soil Type III. Mid-Slope near the Kareli Road

Surface Vegetation.—The ground is covered with dense vegetation. The following table gives the distribution and abundance of the trees.

Sl. No.	Name of species	Frequency	Abundance	Dominance
1	*Butea monosperma*	5	4	3
2	*Diospyros melanoxylon*	4	5	3
3	*Annona squamosa* Linn.	4	5	2
4	*Zizyphus œnoplia*	3	3	0
5	*Acacia leucophlœa* Willd. ..	2	1	1
6	*Holoptelia integrifolia* Planch. ..	1	1	2
7	*Lannea grandis*..	1	1	1
8	*Cassia fistula* Linn.	1	1	0

Though the number of species is not large the forest cover is quite thick. The dominating species are *Butea monosperma* and *Diospyros melanoxylon* both of which grow luxuriously. *Annona squamosa* though quite abundant is often covered by these big trees. The total absence of *Tectona grandis* is notable while the presence of *Acacia leucophlœa* would tend to suggest that the area has not reached the climatic climax type of forest.

Physical Characteristics.—There is a good fall of litter which makes the soil rich in organic matter. Being a slope there is a good surface drainage but the moisture content is still retained well due to dense shade of trees.

S_1—Very dark brown (blackish) in colour, sandy loam, friable. Water-holding capacity is high.

S_2—Lighter in colour, greyish brown, coarser in texture.

S_3—Greyish in colour, mixed with partially weathered parent material and small stones and pebbles.

Chemical Characteristics.—The soil has a high pH which falls in the lower horizons of the profile being 7·7, 7·5, 7·0 in the S_1, S_2 and S_3 respectively. It is rich in organic matter, total nitrogen and exchangeable bases. The exchangeable calcium is highest in top soil and falls in lower depths. Drainage is good and there is ready decomposition of the litter.

Fungal Flora.—

(i) Number of fungi per gram of dry soil:

S_1—1,04,050; S_2—46,020; S_3—14,160.

(ii) Species recorded:

Sl. No.	Name of species	S_1		S_2		S_3	
		F.	A.	F.	A.	F.	A.
1	*Absidia spinosa*	3	2	3	1	..	..
2	*Rhizopus nigricans*	3	2	..	..	..	..
3	*R. nodosus*	2	1	2	1	..	..
4	*Mucor luteus*	1	1	..	..	..	..
5	*Cunninghamella bertholletiæ* ..	2	1	4	2	..	..
6	*C. verticillata*	2	1	..	..	..	..
7	*Saksenæa vasiformis*	1	1	..	..	..	..
8	*Allomyces anomalus* ..	*	..	..	..	..	..
9	*Achlya* sp.	*	..	..	..	..	..
10	*Pythium* sp.	*	..	..	..	..	..
11	*Chætomium* sp.	2	2	..	..	..	..
12	*Phoma hibernica*	3	3	4	3	4	5
13	*Trichoderma lignorum* ..	5	4	..	..	..	..
14	*Aspergillus variecolor* ..	2	1	2	2	3	4
15	*A. ustus*	2	1	..	..	..	..
16	*A. flavipes*	3	1	2	2	..	..
17	*A. terreus*	3	3	3	3	3	2
18	*A. niveus*	2	1	2	2	..	..
19	*A. candidus*	3	2	2	2	..	..
20	*A. niger* (str. 1)	4	4	4	3	3	3
21	*A. luchuensis*	3	1	1	1	3	1
22	*Penicillium nigricans* ..	3	2	3	2	3	2
23	*Gliocladium deliquescens* ..	2	1	2	2	..	..
24	*G. roseum*	..	..	1	1	1	1
25	*Hormodendrum cladosporioides*	4	4	4	5	3	4
26	*Spondylocladium australe* ..	3	1	..	..	..	..
27	*Fusarium nivale*	5	3	4	4	3	3
28	*Fusarium* sp.	3	2	3	3	1	1

* From water culture dishes.

Outstanding Features of the Fungal Flora.—The fungal flora of this soil type was found to be the richest of all the soils studied, both

in quantity and variety. A new genus of Mucorales was discovered from the top horizon. The phycomycetous fungi were found to be commoner in the upper horizon of the profile. The most preponderant species were *Trichoderma lignorum*, *Fusarium nivale*, *Aspergillus niger* and *Hormodendrum cladosporioides*. Species confined to this soil type were *Mucor luteus* and *Saksenæa vasiformis*. A number of aquatic moulds were isolated from the top horizon.

Soil Type IV. Mid-Slope on a West Ridge with Superficial Lime Deposits

Surface Vegetation.—The vegetation is not very thick. The slopes of hills on this side present a denuded and highly eroded appearance. There are only a few species of trees and they also have a poor coverage. The following is the analysis of trees and big shrubs.

Sl. No.	Name of species	Frequency	Abundance	Dominance
1	*Diospyros melanoxylon*	5	5	3
2	*Acacia leucophlœa*	3	3	3
3	*Butea monosperma*	3	3	1
4	*Lagerstrœmia parviflora*	2	3	1
5	*Anona squamosa*	1	3	1
6	*Saccopetalum tomentosum* ..	1	2	1
7	*Carissa spinarum*	1	2	1
8	*Flacourtia ramontchi*	1	1	1

The predominant species are *Diospyros melanoxylon*, *Acacia leucophlœa* and *Butea monosperma*. Many of the species recorded are pioneer species such as *Flacourtia ramontchi*, *Acacia leucophlœa* and *Butea monosperma* indicating that the forest is still in an early transitory stage towards the climax type.

Physical Characteristics of Soil.—The soil is black, well drained and with a fair amount of organic matter. The water-holding capacity is high though the surface is more exposed with consequent loss of water by evaporation.

S_1—Soil is clayey loam, sticky, the surface soil is whitish due to superficial deposit of calcium by the underground spring waters. Large number of big and small boulders are present. Water-holding capacity is moderately high.

S_2—The soil is lighter in colour and coarser in texture than S_1.

S_3—The soil is greyish, full of small stones and pieces of unweathered rock.

Chemical Characteristics.—The pH is high, ranging from 7·5–8·0. The top layer is full of transported calcium and is rich both in exchangeable calcium (2–2·5%) and carbonates (3–5%). The quantity of lime diminishes with the depth of horizon. The soil is also rich in organic content and nitrogen content.

Fungal Flora.—

(i) Number of fungi per gram of dry soil:

S_1—56,280; S_2—16,600; S_3—2,290.

(ii) Species isolated:

Sl. No.	Name of species	S_1		S_2		S_3	
		F.	A.	F.	A.	F.	A.
1	*Absidia spinosa*	3	2	4	4	4	5
2	Phycomycetous sterile mycelium	1	1	..	..	..	..
3	*Phoma hibernica*	3	2	..	..	..	..
4	*Trichoderma lignorum* ..	4	3	4	4	4	5
5	*Aspergillus fumigatus* (str. 1) ..	3	2	3	3	..	..
6	*A. fumigatus* (str. 2)	2	2	3	3	..	..
7	*A. ustus*	..	..	3	2	..	..
8	*A. terreus*	3	2	4	2	3	2
9	*A. candidus*	3	2	..	..	..	..
10	*A. niger* (str. 1)	4	4	4	4	..	..
11	*A. flavus*	3	2	..	..	..	..
12	*Pœcilomyces varioti*	2	2	2	1	..	..
13	*Penicillium funiculosum* (str. 2)	3	2	2	3	..	..
14	*P. nigricans*..	3	3	..	..	..	..
15	*Hormodendrum cladosporioides*	4	3	4	4	..	..
16	*Curvularia lunata*	2	2	1	1	..	..
17	*Spondylocladium australe* ..	2	2	2	1	2	2
18	*Fusarium nivale*	3	4	4	3	3	4
19	*Fusarium* sp.	3	3	4	3	3	4

The predominant species in S_1 horizon are *Trichoderma lignorum*, *A. niger* and *H. cladosporioides*. The number of Mucorales both in quantity and number of species is much less in this soil.

Soil Type V. Grassland on the South-East of the Hills near Patharia Ahir

Surface Vegetation.—The locality is a preserved grassland which is guarded against grazing till the grasses are harvested for hay. There

are only a few trees scattered sporadically and hence no detailed analyses by quadrats was recorded for the area. Among these scattered tree flora there are a large number of saplings of *Butea monosperma* which is kept in check by cutting and eradication, the other tree species are *Acacia leucophlœa*, *Flacourtia ramontchi* and *Elœodendron glaucum*. The main grasses which compose this grassland are *Dichanthium annulatum* Stapf., *Bothriochlœa pertusa* Willd., *Iseilema anthephoroides* Hack. and *Dichanthium caricosum* A. Camus. Other grasses which would come second in order of frequency and abundance are *Heteropogon contortus* Rœm., *Setaria glauca* Beau., *Digitaria royleana* Prain. and *Eragrostis* spp. Other herbaceous weeds which grow mixed along with the grasses are *Heylandia latebrosa* Dc., *Indigofera* spp., *Spermacoce stricta* Linn.f., *Zornia diphylla* Pers., *Alysicarpus* spp., *Polygala chinensis* Linn., *Phyllanthus maderaspatensis* Linn., *Biophytum sensitivum* DC. and *Euphorbia thymifolia* Linn.

Physical Characteristics.—The soil is typically of 'black cotton soil' type or 'regur'.

S_1—Soil is black and full of large quantity of undecomposed grass roots which keep the soil bound up. Clayey loam and sticky to touch when wet. Water-holding capacity is high.

S_2—Greyish black in colour, lighter in colour and coarser in texture than S_1.

S_3—More greyish and lighter in colour than S_2. Small whitish concretions of calcium carbonate are mixed up with the soil. This may be due to some intertrappean lime deposit. Soil is gritty and mixed up with small pebbles and stones.

Chemical Characteristics.—The pH is high, ranging from 7·0–8·0 which increases with depth of the soil. The values of exchangeable calcium is also high, increasing in the lower parts of the profile reaching as high as 11–12% in some estimations. Similarly carbonate values are also quite high. The soil is rich in organic matter and nitrogen content.

Fungal Flora.—

(i) Number of fungi:

S_1—70,520; S_2—26,160; S_3—9,760.

(ii) Flora isolated:

Sl. No.	Name of species	S_1		S_2		S_3	
		F.	A.	F.	A.	F.	A.
1	*Absidia spinosa*	3	2	3	2	3	4
2	*A. butleri*	..	..	..	..	2	2
3	*Cephalosporium acremonium* ..	..	..	3	2	..	..
4	*Cephalosporium roseo-griseum* sp. nov.	3	2	..	..	..	..

TABLE (*Contd.*)

Sl. No.	Name of species	S_1		S_2		S_3	
		F.	A.	F.	A.	F.	A.
5	*Trichoderma lignorum* ..	3	3	4	3	3	4
6	*Aspergillus variecolor* ..	..	..	3	2	2	3
7	*A. flavipes*	3	2	..	..	..	..
8	*A. sydowi*	2	2	..	..	..	..
9	*Aspergillus versicolor* ..	3	2	3	4	..	..
10	*A. terreus*	3	2	3	2	..	..
11	*A. niveus*	3	2	..	..	..	..
12	*A. candidus*	4	2	4	2	..	..
13	*A. niger* (str. 1)	5	4	4	4	..	..
14	*A. niger* (str. 2)	3	2	..	..	..	..
15	*A. luchuensis*	..	..	3	2	3	3
16	*A. flavus*	..	..	4	2	4	3
17	*A sclerotiorum*	2	1	..	..	..	..
18	*Penicillium nigricans* ..	4	2	5	2	..	..
19	*P. terlikowskii*	3	2	3	2	..	..
20	*P. funiculosum* (str. 1) ..	..	..	3	2	..	..
21	*P. lilacinum*	3	2	5	2	5	4
22	*Monocillium indicum* gen. et sp. nov. ..	2	2	3	2	..	..
23	New (genus ?) Moniliaceæ ..	2	2	3	2	..	..
24	*Hormodendrum cladosporioides*	3	4	5	4	4	4
25	*Alternaria humicola*	..	..	..	..	2	2
26	Dark sterile mycelium	..	..	3	1	2	1
27	*Fusarium nivale*	3	2	4	3	4	3
28	*Fusarium* sp.	2	2	2	3	3	2

The soil is very rich in fungal flora both in the number of species and total quantity. Several new forms were found in this type. A new genus named *Monocillium indicum* and two new species of Moniliaceæ were recovered.

Another remarkable feature is the occurrence of a number of species of *Penicillium*. Penicillia were usually very few in other soils. *Alternaria humicola* was found only in the lowest horizon of the profile. Mucorales were poorly represented, the only species being *Absidia spinosa*.

Soil Type VI. Red Soil on Outcrop of Vindhyan Sandstone

Surface Vegetation.—This is a more or less denuded and eroded area of Vindhyan sandstones which merges with the trap rocks. There are hardly any trees excepting stray individual plants of *Acacia leucophlœa* and *Butea monosperma* which are the pioneer species invading the area. The dominant plant is *Agave* sp., which appears to flourish very well in these conditions. No quadrats were laid for the analyses of vegetation.

Physical Characteristics.—The soil is red in colour formed from the ferruginous sandstones. It is coarse in texture having a sandy feel. There are lot of boulders and pebbles mixed with the soil.

S_1—Deep red, sandy, mixed with grass roots and roots of small leguminous herbs. Water-holding capacity is poor.

S_2—Same as S_1 but lighter in colour and with diminished quantity of plant roots. Stone pieces are mixed up.

S_3—Consisting mostly of partially weathered parent rock. Light in colour.

Chemical Characteristics.—The soil is slightly acidic in nature with a pH of 6·5. It is very low in exchangeable bases. The organic content is fairly high but this appears to be due to poor microbiological activity which leaves the matter undecomposed with consequent accumulation. The soil is unprotected from the blazing sun of summer and gets extraordinarily desiccated.

Fungal Flora.—

(i) Number of fungi per gram of dry soil:

S_1—15,610; S_2—10,570; S_3—680.

(ii) Species isolated:

Sl. No.	Name of species	S_1		S_2		S_3	
		F.	A.	F.	A.	F.	A.
1	*Absidia spinosa*	3	3	3	3	2	4
2	*Phoma hibernica*	4	4	3	1	..	..
3	*Aspergillus fumigatus* (str. 2) ..	3	3	2	3	..	..
4	*A. terreus*	2	1	2	4	3	4
5	*A. niger* (str. 1)	4	5	3	4	5	5
6	*Penicillium nigricans* ..	3	2	3	4	..	..
7	*P. funiculosum* (str. 2) ..	3	4	3	2	..	..
8	*Pœcilomyces varioti*	2	2	3	2	..	..
9	*Hormodendrum cladosporioides*	4	2	4	3	3	4

The soil is extremely poor in fungous content both in the number of species as well as quantitatively. Moisture appears to play a decisive role in this soil since the soil gets totally parched during summer and only such species can live which can face such exacting conditions. The soil type presents poineer conditions both for the higher vegetation and the fungi.

Soil Type VII. Ghatera Forest

Surface Vegetation.—The site selected for study is a part of the stabilised bank terrace of the river. No quadrats were laid for detailed analyses of the vegetation; but records were taken after carefully scanning through the vegetation. The dominant species was *Tectona grandis* which constituted about 25% of the trees. The codominants were *Butea monosperma* and *Acacia leucophlœa* indicating that the forest is still in a transitory stage. Other species, in varying proportions, were *Stereospermum suaveolens* Dc., *Dalbergia paniculata* Roxb., *Bridelia retusa*, *Saccopetalum tomentosum*, *Terminalia tomentosa*, *Diospyros melanoxylon*, *Lagerstrœmia parviflora* and *Emblica officinalis*.

Physical Characteristics.—There is a good fall of litter due to a dense coverage. The soil is grey to dark grey with low water-holding capacity.

S_1—Dark grey in colour, sandy loam with good amount of organic matter.

S_2—Greyish in colour which is lighter than S_1. Stray concretions of lime present.

S_3—Same as S_2.

Chemical Characteristics.—The soil is basic in reaction, pH ranging from 7·5–8·0, The figures for organic matter are rather low taking into consideration the abundant fall of litter. This appears to be due to the vigorous microbiological activity which results in rapid loss of carbon in respiration of the organisms. The factors favourable to this intense microbiological activity are the good aeration and a good quantity of soil nutrients. The soil is rich in exchangeable bases and the nitrogen content is also high. Though the water-holding capacity of the soil is low the soil affords to keep moist even in summer due to the dense shade of the trees.

Fungal Flora.—

(i) Number of fungi per gram of dry soil:

S_1—54,920; S_2—9,530; S_3—5,810.

(ii) Species isolated:

Sl. No.	Name of species	S_1		S_2		S_3	
		F.	A.	F.	A.	F.	A.
1	*Rhizopus nigricans*	3	2	..	..	..	..
2	*Cunninghamella verticillata* ..	3	2	..	..	..	..
3	*Achlya* sp.	*		..	..	..	..
4	*Dictyuchus monosporus* ..	*		..	..	..	..
5	*Pythium* sp.	*		..	..	..	..
6	*Phoma hibernica*	3	2	3	3	3	3
7	*Sphæronema* (*spinella* ?) ..	3	1	..	..	..	..
8	*Cephalosporium acremonium* ..	4	3	..	..	..	..
9	*Trichoderma lignorum* ..	4	4	4	4	..	..
10	*Aspergillus terreus*	..	..	2	2	..	..
11	*A. candidus*	3	2	..	..	..	..
12	*A. niger* (str. 1)	5	4	4	5	4	5
13	*A. niger* (str. 2)	3	3	3	2	3	4
14	*A. luchuensis*	2	1	..	..	..	..
15	*A. flavus*	3	2	3	2	2	3
16	*Penicillium nigricans* ..	3	2	3	2	..	..
17	*P. funiculosum* (str. 1) ..	..	..	2	2	..	..
18	*P. lilacinum*	3	2	2	2	..	..
19	*Gliocladiopsis sagariensis* ..	2	2	..	..	..	..
20	*Acrostalagmus cinnabarinus* ..	2	2	..	..	..	..
21	*Pæcilomyces variotii*	3	2	3	2	3	3
22	*P. fusisporus* sp. nov. ..	3	2	..	..	..	..
23	*Scopulariopsis brevicaulis* ..	2	1	..	..	..	..
24	*Nigrospora sphærica*	1	1	..	..	..	..
25	*Curvularia lunata*	3	2	2	2	..	..
26	*Alternaria humicola*	..	..	2	3	4	3
27	*Fusarium* sp.	3	4	4	3	3	3

* Isolated from water culture dishes.

The flora recovered from this type is very rich both in quantity and variety of species. One new genus (*Gliocladiopsis sagariensis*) and one new species (*Pæcilomyces fusisporus*) were discovered from S_1 soil. Other notable species, which were not found in any other soils, were *Sphæronema* (*spinella* ?), *Acrostalagmus cinnabarinus*, *Scopulariopsis brevicaulis* and *Nigrospora sphærica*. Among the Mucorales only *Cunninghamella verticillata* and *Rhizopus nigricans* were collected. *Absidia spinosa* so common in other forest soils was totally absent from this type.

Interpretation of Data: Discussion and Conclusions

General

The data collected for each type of soil fall mainly under (1) Physical characteristics; (2) Chemical characteristics; (3) The type of surface vegetation; and (4) The nature of fungal flora. Obviously, it is not easy to interpret and correlate the various observations which depend upon such a large number of factors.

When any phenomenon is governed by a large number of variables, specially when some of these tend to drive it in one direction and others do the same in the reverse direction, it becomes very difficult to understand and interpret the role of different factors. In case of studies of soil we are confronted with such a situation. The nature of the parent material, texture, pH, organic content, base status, aeration and moisture all effect the soil and the fungous flora in one way or the other. It is, therefore, unsafe to attribute any particular observation to any single factor unless the factor assumes a cardinal importance and becomes a 'limiting factor' which seldom occurs. Further, the so-called 'law of compensating factors' needs mention in this connection. "The idea embodied in this law is simply that excellence in one factor may compensate, within limits, for poverty in another. A factor which is present in minimum need not be strictly limiting; other factors which are unusually favourable may enable the plant to utilize better this factor in minimum (Hesselman, 1926; Wittich, 1930; Wiedmann, 1934)" (quoted in Lutz and Chandler, 1946).

In the light of the above observation and with a view of resolving the complex situation into some understandable form it is proposed to consider the data under the following 3 titles:—

(i) Consideration of edaphic factors with respect to distribution and abundance of fungi as a whole.

(ii) The distribution and behaviour of various groups of fungi in different soils.

(iii) Fungal flora of different soils with respect to possible successional sequence and its correlation with surface vegetation.

Edaphic Factors and Fungi

Vertical distribution of fungi in the profiles.—In general it may be said that the number of fungi goes on decreasing downwards in the profile. The top 6 inches of the soil contain the maximum number of fungi which falls gradually as the lower horizons are reached. This observation is in concordance with many other workers. Cobb (1932) recorded that fungi are 10 times as abundant in the top zone under hemlock trees as in the sub-soil. Takahashi (1919) found 5,90,000 fungi per gram of soil at a depth of 2 cm. and 1,60,000 at 8 cm. Goddard (1913) in Michigan and Werkinthin (1916) in Texas found similar results.

This vertical distribution is usually accounted by the fact that fungi are pronounced aerobes and would not thrive in deficiently aerated lower horizons of soil.

From the aforesaid it will be seen that there is a sudden fall in the number of fungi from S_1 to S_2 excepting in soil type VI in which we find that the fall is not so abrupt. From the detailed data it was seen that in one of the isolations which was done in the month of May the number of fungi (7,710) in S_1 was found to be actually less than (10,750) in S_2. As earlier stated this soil is badly exposed and denuded of vegetation. In summer very few fungi can survive in the upper dry layer which is intensely desiccated. This point is dealt with in details in connection with moisture relations below.

Moisture Relations

Moisture as a rule is favourable for the growth of fungi as long as there is no water-logging when the consequent anaerobic conditions begin to play against them. In such conditions only those forms thrive which are adapted to aquatic conditions such as species of *Allomyces*, members of Saprolegniaceæ and Pythiaceæ. Such aquatic moulds were recovered from soil types III and VII.

Averages of moisture content of different soils are of little use for the purpose of comparisons because a particular determination of moisture content will depend upon the condition of soil at the time of collection. This condition can vary from almost total saturation after a good fall of rain to a stage of almost perfect desiccation which occurs in exposed and open soils during summer months.

In the latter conditions moisture becomes a factor of cardinal importance and limits the growth and development of fungi. In the present context soil type VI presents such a case. The ground is more or less denuded of vegetation, the surface cover consists mainly of stunted grasses and legumes and sparsely spread plants of *Agave* sp. Soils collected in the months of February and September show a moisture content of 9·8% and 12·5% respectively in the S_1 horizon and the number of fungi collected are 18,940 and 20,180 per gram respectively. But, the sample collected in the month of May had only 4·3% of moisture and the number of fungi was only 7,710 which was less than that what was found in S_2 horizon (10,750) at the same time of collection. (Only averages are given in Table I).

Another interesting feature is the nature of fungal flora in such conditions. There are only a few species which can stand the drought conditions of the S_1 layer. Physiological literature on the moisture requirements of fungi tends to indicate that the moulds show a vastly different capacity to face dry conditions. "The minimum relative humidity at which fungi are able to grow is correlated with the concentration of the cell sap and consequently with the suction pressure exerted by the hyphæ" (Hawker, 1950). The survival from a long drought depends upon the capacity of resting spores possessing thick walls and lack of vacuoles. In the present instance such species would appear to be *Absidia spinosa*, *Phoma hibernica*, *Aspergillus fumigatus* (str. 2), *Aspergillus niger* (str. 1), *A. terreus*, *Penicillium funiculosum* (str. 2), *Pæcilomyces varioti*, *Penicillium nigricans* and *Hormodendrum cladosporioides*.

As has been mentioned above, the actual amount of water in any sample of soil is highly variable according to the conditions of weather and does not express any intrinsic quality of soil. It was, therefore, thought desirable to determine the water-holding capacity of different soil samples. Though there are so many factors which govern the abundance of fungi in soils a general relationship does exist between the water-holding capacity and the average number of fungi. The fungal flora of a soil with high water-holding capacity is better equipped to face drying conditions.

It may be remarked here that in most of the relevant literature on soil fungi, which has been published on the work done in countries of cooler climate, no such emphasis has been laid on the moisture content of the soil. It is because in those cases the content of water in soils does not fall below the critical point for a larger duration during the year.

Reaction of the Soil

A perusal of the Table I for pH figures would show that pH values of all the soils range between a narrow limit of 6·4–8·0. With the exception of two soil types, *viz.*, Nos. I and VI all the rest are distinctly alkaline. These two soils are slightly acidic, the lowest pH recorded being 6·2. (Only averages are given Table I.) It is further seen that the soil pH is closely related with the exchangeable calcium. The greater the quantity of exchangeable calcium the more alkaline is the soil.

The earlier literature is full of indications that the fungi flourish in acid soils and bacteria predominate in alkaline soils. Jensen (1931), however, has remarked that since the work of Ramann *et al.* (1899) it has been nearly a dogma in soil microbiology that " fungi prevail in acid, bacteria in neutral and alkaline soils". It is now well recognised that fungi are abundantly found in the alkaline soils and play a good part in the microbiological activity of such soils (Waksman, 1927; Jensen, 1931).

A perusal of the physiological literature on the subject shows that fungi are tolerant of a wide range of hydrogen-ion concentration, that is from pH 3–9. Most fungi have the optimum growth at neutral reaction or slightly on the acid side of neutral (Hall, 1933; Hawker, 1950). Bacteria also occur universally in soils but in general, they are less tolerant of the acid conditions (Waksman, 1932). The abundance of fungi in an acid soil is due to a lessening of competetion with bacteria which tend to decrease in such conditions, rather than any favourable effect of pH on fungi.

During the course of the present studies only two soils were found to be slightly acidic, *i.e.*, Nos. I and VI with an average pH of 6·5 and 6·4 respectively. The average number of fungi isolated from the top horizon of these soils were 46,890 and 15,610 the first one of which compares almost *at par* with other soils of higher pH but the second soil is very poor in the fungal content. It should be mentioned here that the second soil has several unfavourable factors, *e.g.*, low base status, deficient water-holding capacity, etc. An apt suggestion from

the foregoing would be that slight acidity in soils under the tropical conditions does not very much favour the growth of fungi.

Organic Matter

The organic matter is maximum in the surface layer in all the soil types and falls in the lower horizons of the profiles. The highest average recorded was 4·1% for the grassland and the lowest 2·22% in types VI and VII.

Organic matter is a very important constituent of the soil and is effective in 3 important ways. Firstly, on decomposition it releases the various nutrients to the soil. Secondly, it increases the colloidal properties of the soil and thus improves its exchange capacity. Thirdly, an increase in the organic matter is conducive to enhancing the water-holding capacity of the soil.

From the data recorded it can be readily seen that there is a direct correlation between the organic matter and the quantity of fungal flora. This observation is in agreement with many other workers. The culture experiments by Jensen (1931) have shown that the presence of decomposable organic matter tends to stimulate the activities of fungi. In nature also he found the maximum fungi in soils rich in organic matter.

The soil type VI again presents a notable exception. There is a fair amount of organic matter (2·22%) though the surface vegetation is poor. The total number of fungi is only 15,610 while with the same amount of orgnic matter the number of fungi is 54,920 in type VII. An acute scarcity of moisture, as discussed earlier, appears to be the factor limiting the development of fungi in this particular case.

Total Nitrogen and Nitrates

The figures indicate that all the soils are well supplied with the total quantity of nitrogen. This is the case at least with top horizon of the profiles. The records for nitrates are, however, rather erratic. The quantity of nitrates in soils, at any given moment, is known to depend upon the nitrification processes which increase their quantity and the absorption by the roots and micro-organisms which reduces them. The observation at any time, therefore, is the resultant of these two processes which go on at varying rates depending upon the conditions in soil.

The quantity of nitrogen is seen to correspond with the quantity of organic matter in various soils and effects the quantity of fungal flora in the positive direction.

Phosphate, Potassium and Iron

The results of analyses show that all the soils are fairly well supplied with these nutrients.

Phosphorus is very important from the point of view of physiology of fungi. It is present in good quantity in the moulds and should be present in sufficient quantity in the soil to support good growth of

fungi. Potassium, though needed in a very small quantity, is also essential. Fungal ash shows comparatively little of this element than the ash of higher plants. Iron is regarded as a trace element in the physiology of fungi (Hawker, 1950).

Since quantities of these constituents are sufficient in these forest soils and requirements of fungi low in this respect, a more critical examination of these constituents seems unwarranted.

Exchangeable Calcium and Carbonate Content

Calcium from the standpoint of soil characteristics is of prime importance since it exerts a strong influence on the physical, chemical and biological characteristics of soil. The presence of calcium promotes the aggregation of the soil colloids and gives the soil the crumb structure which improves the aeration and drainage and thus favours plant growth and the growth of micro-organisms. It also helps in neutralising the acids produced by the micro-organisms and reduces the toxicity in soils thus promoting the growth and activity of the microbial population.

The soil may contain a substantial amount of calcium in insoluble form which may not be directly available. A good amount is usually present in exchangeable form in the colloidal complex of the soil which is directly available for absorption by the plants.

An examination of the data of exchangeable calcium shows that there is a wide variation in the quantity present in different soils. The vertical distribution of calcium is also not uniform in the profiles of different soils, for example, in the soil type III the maximum is in the top horizon and there is a decrease in calcium with depth of soil; but in soil type V (grassland) this vertical distribution is reversed in quantities.

From the data it is also deducible that the fungal content of the soil is favourably affected by the exchangeable calcium. The highest and the lowest average values recorded for the top horizon were 5·45% and 0·14% which correspond with the highest and the lowest figures for the number of fungi respectively, these being 1,04,050 and 15,610.

Summing up the effect of various edaphic factors on the quantitative abundance of fungi in soils, we can say that the organic matter, exchangeable calcium, pH value, nitrogen content, water-holding capacity and the degree of surface cover has the greatest influence on the development of fungi.

An idea of the integrated effect of all these factors playing together can be had from the polygraphs given in Fig. 2.

Distribution of Various Groups of Fungi in Different Types of Soils

It is not easy to place the various fungi into distinct ecological groups. Such groupings can obviously be very approximate since the relationship of a soil fungus to its habitat is determined by its physiological and biochemical characteristics in many of which every possible

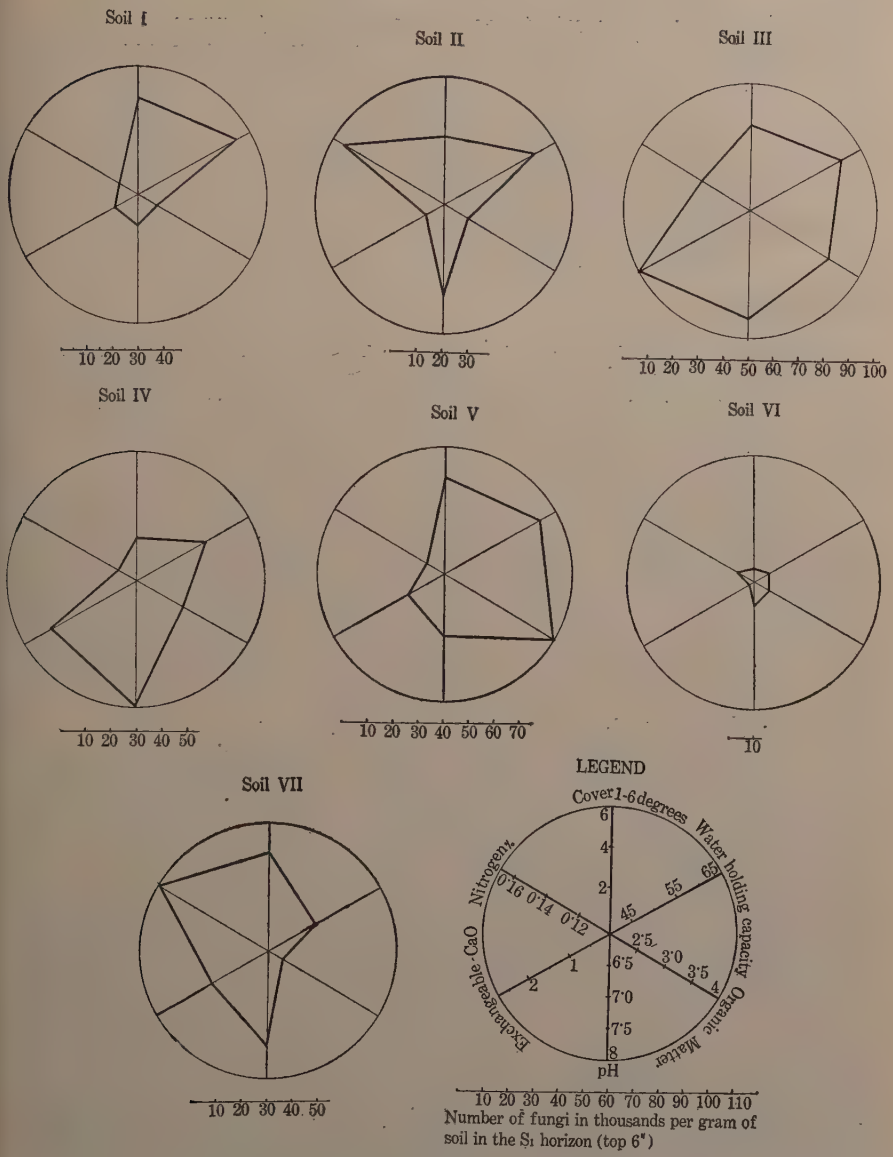

FIG. 2. Polygraphs showing the abundance of fungi along with 6 important soil factors in the 7 types of soils.

gradation is to be found. For example, it is difficult to classify soil fungi into cellulose decomposers or non-cellulose decomposers since the capacity of decomposing cellulose may vary in different fungi from very feeble to very strong (Garrett, 1951). But, in spite of these difficulties it has been possible to group these fungi to a certain extent

depending upon the substrate or the particular nutrient in the substrate which favour their development. A few relevant examples are:—

(i) 'Sugar fungi'—Comprising largely of Phycomycetes which readily decompose the various sugars.

(ii) 'Cellulose decomposing fungi'—Comprising of various Ascomycetes and Fungi Imperfecti.

(iii) 'Lignin decomposing fungi'—Comprising of Basidiomycetes (Waksman, 1952).

Phycomycetes

These are the 'sugar fungi' which are the pioneer colonizers of the dead plant and animal tissues for which they are ecologically equipped by an exceptionally high growth rate and readily germinating spores. They usually preponderate in the upper horizon which is rich in the undecomposed or partially decomposed organic matter.

During the course of these studies 12 species covering 9 genera were in all isolated. Such aquatic moulds as species of *Allomyces*, *Achlya*, *Dictyuchus* and *Pythium* were recovered from the water culture dishes on hemp seeds. It may be remarked here that with the studies of Harvey (1925) there has been a lively interest in the isolation of water moulds from soils. The aquatic moulds were collected from soil types III and VII which remain rich in moisture content due to a thick tree cover; from other soils they were found to be absent probably due to the desiccating effect of the summer drought.

Among the Mucorales, *Absidia spinosa* was found to be the commonest. It was absent only from soil type VII which is the only alluvial forest soil studied. In other soils it was found to occur throughout the profiles reaching upto deepest layers. This would suggest its adaptability to deficiently aerated conditions. The frequency distribution of this fungus is given in Fig. 3. Another species of *Absidia*, *A. butleri*, was queer in being recovered only from the innermost horizon of soil type V. It was not found in any other soil. *Rhizopus nigricans*, *Cunninghamella bertholletiæ* and *C. verticillata* were fairly common in top zone of many soils. Only one species of *Mucor*, *M. luteus*, could be collected in the entire studies. This is rather surprising. But, it is in conformity with many other workers who have found Mucor very infrequently in soils of hot climate (Waksman, 1917; Werkinthin, 1916; Galloway, 1936). A new genus of Mucorales which showed very interesting features was discovered from soil type III. The genus *Zygorhynchus* so commonly reported by many workers could not be encountered in any of the isolations.

Ascomycetes

The only member of the Ascomycetes found was *Chætomium* sp. which was isolated form soil types II and III. Aspergilli with perithecial stages are placed under Moniliales along with other non-perithecial forms. *Chætomium* has been recorded in soils by many other

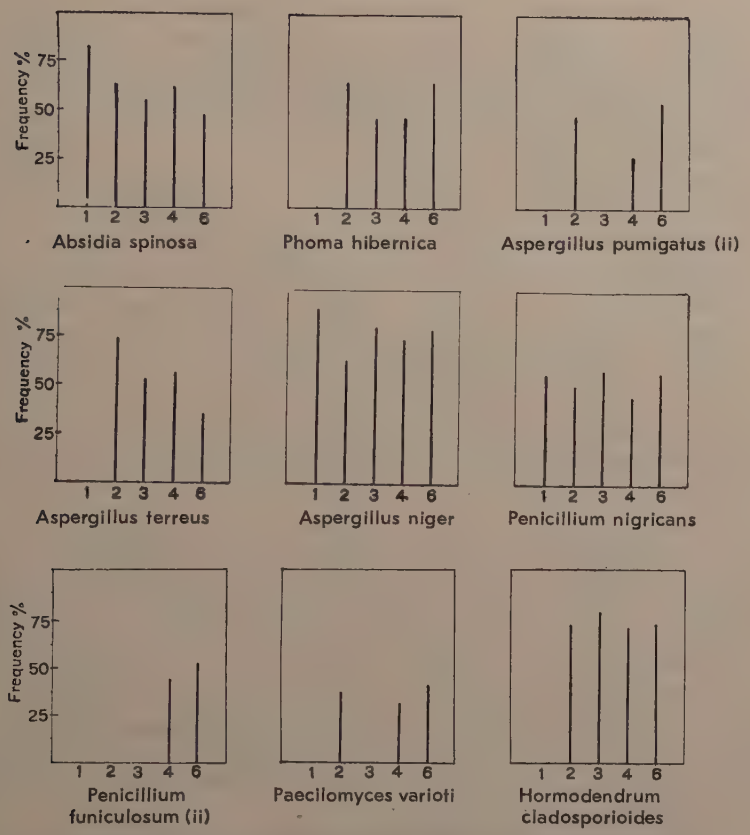

FIG. 3. Showing the frequency and distributional behaviour of 9 species of fungi in the various forest soil types.

workers. It has been known since long that species of *Chætomium* can digest cellulose (Waksman, 1927).

Deuteromycetes (Fungi Imperfecti)

Members of this group along with Ascomycetes are pronounced cellulose decomposers which multiply and grow luxuriantly in all soils with organic matter. The account of the members isolated are given below:—

Sphæropsidales.—Two genera, *viz.*, *Phona* and *Sphæronema*, were collected. *Phoma hibernica* was common in many soils and appears to have good ecological tolerance. Its vertical distribution in soils is also good. *Sphæronema* was isolated by Waksman (1917) from a soil in U.S.A.

Moniliales.—Members of the Moniliales are the most important part of the fungal flora of soils. They are well known for their cellulose

decomposing powers. Kellerman and McBeth (1912) had shown that species of *Aspergillus*, *Fusarium*, *Penicillium* and *Sporotrichum* utilize cellulose as nutrient in pure cultures. Daszewska (1913) found that various Hyphomycetes are more important in cellulose decomposition than are bacteria and that the colour of the humus formed is related to that of mycelium and conidia.

In the present series of investigations 32 species of 9 genera were isolated. The most important genera are *Aspergillus*, *Trichoderma*, *Cephalosporium*, *Penicillium* and *Gliocladium*.

Aspergillus was found to be the most important genus and 16 species (including forms) were isolated. Every type of soil had some species or the other though the species differed in their distribution. *A. niger*, *A. candidus*, *A. flavus* and *A. terreus* were found to have a wide distribution. *A. niger* was found in all the 7 types of soils studied. By other workers as well, the black Aspergilli have been found to be more common than any other representative of the genus. They are worldwide in distribution and are abundantly found in all soils particularly so in soils of tropical and sub-tropical areas (Thom and Raper, 1945).

A few species of *Aspergillus* showed rather a restricted distribution, *e.g.*, *A. sclerotiorum* was found only in soil type V. *A. sclerotiorum* does not appear to be reported from soil as far as known to the writer. It agrees closely with the description based on Huber's collection (Thom and Raper, 1945) which was isolated from rotting apples in Oregon.

The next important genus was *Penicillium*. Five species were, in all, isolated including 2 strains of *P. funiculosum*, *P. nigricans* was of the widest distribution having been recovered from all the soil types, next in order was *P. lilacinum*. On the other hand *P. terlikowskii* was found only in soil type V.

The occurrence of Penicillia in the soils studied is poor compared to that of Aspergilli. This is in concordance with the observations of many other workers who are all agreed that *Aspergilli* are common soil fungi of the warmer parts of the earth while the Penicillia abound in colder regions (Waksman, 1917; Werkenthin, 1916; Jensen, 1931). The Aspergilli are a group of somewhat thermophilic organisms which thrive very well at 35–40° C. where most Penicillia die (Jensen, 1931).

Other notable genera of Moniliaceæ which were found to be of wide occurrence are *Trichoderma* and *Cephalosporium*. *Trichoderma lignorum* was collected from all the soil types excepting VI. It may be mentioned here that Galloway (1936) found a restricted occurrence of the genus *Trichoderma* in his studies on Indian soil fungi. This may be due to the fact that many of his soils were collected from colder regions of Himalayan hills. Waksman (1917) mentions that *Trichoderma* was more prevalent in moist situations. In the present investigations it was found in all soils except one which was the driest. Species of *Gliocladium* were common in soil types I and III. Two other genera which are commonly reported from soils, *Acrostalagmus* and *Scopulariopsis* were confined to soil type VII. Two new genera one named as

Gliocladiopsis and the other *Monocillium* were discovered from soil types VII and V respectively. One new species resembling *Hormodendrum* in having acrogenous chains of conidia but characterised by totally white colonies and spores, was found in soil type V.

Dematiaceæ.—Five genera and 6 species were collected. *Hormodendrum cladosporioides* was reported from 5, *Spondylocladium australe* from 2 and *Curvularia lunata* from 3 soils. *Alternaria humicola* which was recovered from soil types V and VII was found to occur only in the lower horizons.

Tuberculariaceæ.—Species of *Fusarium* were quite common. *Fusarium nivale* was isolated from soil types I, II, III, IV and V. Another species which could not be exactly identified was also equally common. They were found to be absent in soil type VI.

Fungal Flora of Different Soils with respect to Possible Successional Sequence and its Correlation with Surface Vegetation

The data on the higher vegetation show that there are different vegetation types which can be said to be at different stages of succession on the 7 types of soils. Is it true for the fungous flora as well?

The information from the past work tends to suggest that there does exist a definite type of fungal flora for a particular type of soil. Brown (1917) states that "different soils undoubtedly have different fungous floras". Waksman (1916) found no radical difference between the species of fungi from cultivated and uncultivated soils. However, he stated that "each soil seems to have a more or less characteristic fungous flora". Dale (1912, 1914) studied the fungous flora of sandy, chalky, uncultivated peat and 'black earth' soils and found specific differences, although many of the species were common to all these types of soils. Goddard (1913) found the fungous flora of different soils to be uniform. Very recently Warcup (1951) has studied the soil fungi of grassland in England and Tresner *et al.* (1954) have carried out a survey study of microfungal flora of soils of upland hardwood forests in Southern Wisconsin. The results in both the cases tend to indicate that the character of the microfungal population does vary considerably from one ecological area to another and that the distribution of various species is influenced by higher plant cover, the amount and character of the organic matter and other factors.

In the present studies 7 different soils which support distinct forest types or surface vegetation have been studied. Forest types studied comprise of, right from scrub type with stray vegetation (soil type VI) to the dense forest type which represents the climatic climax of the area (soil type I). A natural question which can be posed now is: Do we have a parallel successional sequence in the distribution of microfungi as well?

While dealing with the individual forest types it has been seen that the poorest area was Type No. VI which supports only stray trees of *Acacia leucophlœa* and *Butea monosperma*, which are the well

known pioneer species of the area, and plants of *Agave* sp., besides a few herbs. The next successional stage of forest is found on soil type IV where the forest stand is better but the trees are still scattered and consist of such species as *Acacia leucophlœa*, *Butea monosperma* and *Diospyros melanoxylon*. The third in order would be soil type II where the forest has become quite dense but has not yet reached the climax stage; the dominant vegetation, in this case, consists of *Tectona grandis*, *Diospyros melanoxylon*, *Butea monosperma* and *Anogeissus latifolia*. The climax stage is found in Type I where the stand is very thick and the dominant trees are *Anogeissus latifolia*, *Nyctanthes arbotristis*, *Tectona grandis*, *Diospyros melanoxylon* and *Terminalia tomentosa*. The type III, on a midslope, is also a thick forest which would stand between the climax type I and type IV but has a different successional pattern than type II; here, *Tectona grandis* is totally absent and the dominant trees are *Butea monosperma*, *Diospyros melanoxylon* and *Anona squamosa*. [In the present context, types V and VII are omitted since the former is a pure grassland and the latter is a forest on fundamentally different soil (alluvium) which is situated 60 miles away.]

The fungal flora of soil type VI which supports the pioneer type of vegetation may be considered first. There are only 9 species of fungi found in this soil (*vide* page 281). These can be termed as pioneer species if the terminology used in the study of ecology of higher plants is applied. If the distribution pattern of these 9 species is studied, as given in Fig. 3, some interesting facts are revealed. There are 3 species *viz.*, *Absidia spinosa*, *Aspergillus niger* and *Penicillium nigricans* which are found in all the 5 types of soils. These fungi have the highest ecological amplitude. Then there are other 3 species, *i.e.*, *Penicillium funiculosum* (str. 2), *Aspergillus fumigatus* (str. 2) and *Pœcilomyces varioti* which were found in a restricted number of soils—the first one occurring only in 2 soils while latter 2 in 3 soils each. Their environmental tolerance is low comparatively, or they are not able to stand the increasing competition in the climax conditions. The rest are of intermediate types which do start from the pioneer condition but always fall short of reaching upto the climax stage.

Those species which are confined to poor conditions such as *Penicillium funiculosum* (str. 2), *Aspergillus fumigatus* (str. 2) and *Pœcilomyces varioti* may be regarded as good indicators of pioneer conditions. It may be recalled here that *Aspergillus fumigatus* is a thermophilic species and thrives at 45° C. or even higher (Thom and Raper, 1945).

Climax species.—There were a number of species which occurred only in soils of mature forests. *Gliocladium deliquescens*, *Gliocladium roseum*, *Aspergillus variecolor*, *Cunninghamella verticillata* and *C. bertholletiæ* are the most prominent of these. These can be good indicators of the mature and climax types of soils.

Then there are a large number of species much varying in their behaviour, making their appearance at any stage after pioneer conditions and going to different lengths upto the climax or the sub-climax

stages. Naturally there is a lot of overlapping in the distribution of these species and there is no consistent pattern of their distribution.

The total fungal content of the soil and the number of fungal species goes on increasing progressively from the pioneer to the climax type of soils and it is irresistible to draw a parallelism with the higher vegetation in the successional sequence from the pioneer to the climax stages.

Due to a large number of species and their overlapping distribution it was not possible to form discrete communities in which particular forms were consistently associated. This is more or less analogous with the situation as it exists in these forests with respect to higher vegetation.

The two other soils, types V and VII, which were left out of this consideration of successional sequence, have a large number of fungi common with other soils but have a few distinctive features of their own. The grassland soil is very rich in organic content and a large number of species were isolated from it. Mucorales were poorly represented but a large number of Aspergilli were isolated some of them only from this soil, *e.g.*, *Aspergillus sclerotiorum.* A new genus *Monocillium* was also discovered from this type of soil.

Soil VII was studied only as a contrasting type of forest. Here also a very large number of species were isolated. Several fungi were found only to occur in this soil, *e.g.*, *Sphæronema* (*spinella* ?), *Scopulariopsis brevicaulis*, *Nigrospora sphærica.* Mucorales and aquatic forms were well represented.

Summary

An ecological study of the microfungi occurring in the various types of forest soils near Sagar has been made. Geologically the parent rock consists of basalt with some adjacent Vindhyan sandstones. There are two main kinds of soils, one of which is the black cotton soil or the 'regur' and the other is red which is lateritic in nature.

Sites representing 5 different soil types were selected for the study. In addition, one grassland type and one more forest type (Ghatera Forest) on alluvial soil was chosen as a contrasting type. The surface vegetation was recorded by laying quadrats of 25 × 25 feet and the flora was analysed for frequency, abundance and dominance of each tree species.

For the study of fungal flora and soil characters, pits were dug for profile study and samples were taken from 3 different depths, *viz.*, S_1 (0–6″), S_2 (7″–12″) and S_3 (13–18″). For every horizon, the soil was tested and analysed for the determination of physical and chemical characteristics. Fungal flora of each sample was studied by Waksman's dilution plate method. Phytosociological analyses for fungal species was also done.

The number of fungi goes on decreasing downwards in the profile. Moisture was found to play an important part in these soils in the abundance and occurrence of fungi. Very few fungal species could

stand the drying conditions of summar months if the surface was exposed to sun as happened when the soils were denuded of vegetation. Such drought resistant species were *Absidia spinosa*, *Phoma hibernica*, *Aspergillus fumigatus*, *A. niger*, *A. terreus*, *Penicillium nigricans*, *P. funiculosum*, *Pæcilomyces varioti* and *Hormodendrum cladosporioides*.

The quantity of organic matter, nitrogen content and exchangeable calcium were found to be favourable for the multiplication and growth of fungi. The pH did not influence their abundance appreciably; the variation of pH in different soils was not found to be much. Most of the soils were alkaline in reaction ranging between 7·0–8·0 excepting two which were slightly acidic. The lowest pH recorded was 6·2.

An integrated effect of the dominating edaphic factors was found to be more important in the occurrence and distribution of fungi than any single factor which seldom became decisive.

The distribution of various groups of fungi has been studied. The Phycomycetes or the 'sugar fungi' were usually abundant in the top soils. Water moulds such as species of *Achlya*, *Dictyuchus* and *Allomyces* were isolated from humid conditions which kept the soil moist even in dry periods. Among Mucorales, *Absidia spinosa* was found to be the commonest and most resistant to the dry conditions. *Rhizopus nigricans*, *Cunninghamella bertholletiæ*, *C. verticillata* were also quite frequently met with but species of *Mucor* were rare. *Zygorhynchus*, a common soil dweller, was surprisingly absent from all the soils studied. A new genus of Mucorales was found in soil type III.

Only a single genus *Chætomium* was collected from the Ascomycetes. Deuteromycetes were the commonest. Two genera of Sphæropsidales, *Phoma* and *Sphæronema* were isolated. *Phoma hibernica* had a wide distribution. Among Moniliales, *Aspergillus*, *Trichoderma*, *Cephalosporium* and *Penicillium* were the important ones. Aspergilli were the most dominant group. *A. niger* was ubiquitous, other common species were *A. candidus*, *A. flavus* and *A. terreus*. *A. sclerotiorum* was isolated only from soil type V. The species of *Penicillium* were restrictedly found excepting *P. nigricans* which was widely distributed. Species of *Fusarium* were common.

Phytosociological analyses of data of fungal flora revealed that there were pioneer species such as *Penicillium funiculosum* (str. 2) and *Aspergillus fumigatus* (str. 2) which were confined to poor conditions of soil and could stand the trying hot condition. These may serve as useful indicators of such poor soils. On the other hand, there were a number of species which appear only in the climax conditions and which do not appear in earlier successional stages. These are: *Gliocladium deliquescens*, *G. roseum*, *Aspergillus variecolor*, *Cunninghamella bertholletiæ* and *C. verticillata*. These would be good indicators of mature and well developed soils. Finally, there were ubiquitous species which appeared to have a high ecological tolerance; these were *Aspergillus niger*, *Absidia spinosa*, *Penicillium nigricans*. Though these could survive any conditions, their crest of frequency was reached in good and mature soils.

Apart from these there were found to be a host of other fungi which did not fall into any one of these characteristic distributional patterns and have irregular ranges of occurrence.

The number of species and the total number of fungi was found to increase progressively from the pioneer to the climax type of soils and it was revealing to find a striking parallelism with the higher vegetation in the successional sequence from the pioneer to the climax types.

Three new genera and 3 new species were discovered during the course of these studies.

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